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**Abstract:** Reconsidering the relationship between human well-being and environmental quality is central for the management of wetlands and water resources and for public health itself. We propose an integrated strategy involving three approaches. The first is to make assessments of the ecosystem services provided by wetlands more routine. The second is to adopt the “settings” approach, most developed in health promotion, wherein wetlands are one of the settings for human health and provide a context for health policies. Finally, a layered suite of health issues in wetland settings is developed, including core requirements for human health (food and water); health risks from wetland exposures; and broader social determinants of health in wetland settings, including livelihoods and lifestyles. Together, these strategies will allow wetland managers to incorporate health impact assessment processes into their decision making and to examine the health consequences of trade-offs that occur in planning, investment, development, and decision making outside their direct influence.

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Wetlands as settings: ecosystem services and health impact assessment for wetland and water resource management

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Reconsidering the relationship between human well-being and environmental quality is central for the management of wetlands and water resources, and public health itself. We have proposed an integrated strategy involving three approaches. The first is to make assessments of ecosystem services provided by wetlands more routine. The second is to adopt the ‘settings’ approach, most developed in health promotion, where wetlands are the settings for human health and a context for health policies. Finally a layered suite of health issues in wetland settings is developed, including core requirements for human health (food and water), health risks from wetland exposures, and broader social determinants of health in wetland settings including livelihoods and lifestyles. Together these allow for health impact assessment processes for wetland managers to make explicit human health consequences of their decision making, and to examine trade-offs that occur in planning, investment, development and decision-making outside their direct influence.

Keywords: healthy settings, ecosystem services, trade-offs, health impact assessment, wetland management.
The consequences of increased interactions between people and wetland ecosystems have received more attention in recent years (Falkenmark et al. 2007, WWAP 2009, Gordon et al. 2010, Vorosmarty et al. 2010) with particular emphasis on the relationship between ecosystems and human well-being (MEA 2005, Arthurton et al 2007). A meaningful relationship between the well-being of people and the quality of their surroundings, their sources of food and water, is widely held as desirable. For wetlands, in their broadest sense, this desirability is acute: despite producing more food globally and extracting more water globally, wetlands continue to decline, and the capacity of wetlands to provide is diminishing. For many people the public health and living standards have not improved and access to water and sanitation remains problematic. However a negative view of wetland ecosystems held by the public in general and the public health profession in particular, persists. While wetland ecosystems might provide for people directly and indirectly, these benefits are taken for granted, even hidden by the technologies that successfully provide water and sanitation. Rather, a common misunderstanding about wetlands still persists, they are perceived as the source of vectors or water-borne infectious diseases, which pose a sanitation challenge for the safe disposal of human excreta, and make access to health services more difficult for those populations living in and around them; wetlands are therefore ‘the problem’ for human health, rather than the upstream factors that determine disease occurrence. For inland wetlands (including swamps, marshes, lakes and rivers) the importance of developing environmental management strategies that support the maintenance of both wetland ecological character and human health concurrently has been recognized (Corvalan et al., 2005, Finlayson et al. 2005).

The desire to recognize a richer relationship between wetland ecosystems and human health has come from a realization that the harm to human health and well-being caused by environmental change can be disguised by time, scale, and socioeconomic and cultural distances between policy-makers and those who suffer (see for example Butler 2008, referring to forest clearance). In addition, 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, often drawing on a wider scientific base, including ecological and social sciences (Corvalan et al. 2005, Boischio et al. 2009), acknowledging uncertainty and complexity of the systems we are dealing with (Wilcox and Colwell 2005), the need to work across sectors of government (Adelaide Statement on Health in all Policies 2010), and above all (re)learning the interconnectedness, interdependencies and reciprocal relationships between people and their environments (Parkes and Horwitz 2009).

Examples of the complexity of such relationships can be shown by the historical and continuing links between malaria and humans (O'Sullivan et al. 2008), and by the expansive examples of the implications of climate change for reliable access to water resources (Kundzewicz et al. 2007), for water and disease (Confalonieri et al. 2007), and for the biodiversity and poverty alleviation relationship (Boersema et al. 2009).

The ramifications of these imperatives are that professionals managing wetlands and professionals managing public health programmes need to develop skills to enter into a productive dialogue to find optimal solutions in such situations, and in doing so they span a remarkable spectrum. Topics in this dialogue might include the management of flora and fauna, access to harvestable items like timber, fish or edible plants, and the nature of sediment, water regimes and access to water quantities and qualities. Beyond these are the presence of waterborne pollutants, human sanitation, animal health, 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, most will be influenced by local economies, cultural factors, political structure, gender and age-related factors in populations. Compounding factors will occur, like the implications of climate change for human health issues associated with wetlands, and
fragmented approaches in governments (Flinders 2002) like that found between water resource
management and public health. A framework will be useful to constrain this almost infinite list. In
addition, in their dialogue, it is inevitable that choices will need to be made in decision-making where
conflicting outcomes might be reasonably predicted, requiring a trade-off. This paper provides a strategy
for making explicit the trade-offs in wetland management and human health. It is intended to serve as a
guide for decision making that more richly encompasses the interaction between wetland ecology and
management and the health of people in cultural and societal contexts. The paper next deals with the
inclusion of ecosystem services in assessments of wetland ecosystem condition, and how ecosystem
services might be best recognized in a public health discourse.

**Ecological character of wetlands and the inclusion of wetland ecosystem services**

There has been a modern tendency to assess the condition of natural resources, and human well-being
associated with them, separately. For wetlands in their broadest sense (including rivers, lakes, marshes,
rice fields, and coastal areas, and so on), as originally defined by the Ramsar Convention on Wetlands in
1971, ‘condition’ was embedded in two concepts - the *wise use of wetlands* and the *maintenance of
their ecological character*. Using the framework adopted by the Millennium Ecosystem Assessment,
“wise use” has since been equated to the maintenance of ecosystem benefits/services to ensure long
term maintenance of biodiversity as well as human well-being and poverty alleviation, and “ecological
character” as the combination of the ecosystem components, processes and benefits/services that
characterize the wetland at a given point in time (Ramsar Convention 2005). A treatment of the
constituent parts of what makes up ecological character must comprise not just a list of the
components, processes and benefits/services, but what they represent *in combination*. Further, for the
purposes of the Ramsar Convention, the ecological character description of a wetland provides the
reference or baseline description of a wetland at a given point in time (Ramsar Convention, 2005).
Table 1 outlines the breadth of ‘ecological character’ likely to be included in a description of an assessment of a wetland, including physical, chemical and biological components, ecological processes, and an array of ecosystem services: provisioning, regulating, cultural or supporting. The categorization provides a basis for identifying key issues for management consideration and the role of wetlands in supporting human well-being. It is emphasized that not all categories of information in Table 1 apply to all wetlands, and for some, hopefully only a few wetlands, this categorisation may not describe them adequately. In this sense we note the caution expressed by Fisher et al. (2009) toward attempts to come up with a single or fundamental classification system since character will also be determined by complexities introduced by biogeographic and social considerations that are invariably difficult to identify and characterise.

Nevertheless, we use this construct to link human well-being with ecological character through the services that a wetland provides so that human well-being is included in wetland assessments (Figure 1). As human health (“a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity” see WHO 1978) is a central component of human well-being, it becomes linked with the ecological character of wetlands (Figure 1), and is not limited to an absence of disease or illness.

There are broader implications of this for the conservation objective of a wetland management agency that adopts this construct: 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, species biodiversity. This is a useful ‘olive branch’ to sectors who perceive that natural resource management agencies insufficiently consider the human dimension.
Ecological character

included in

to include

Ecosystem services

to recognise

Human well-being

Human health

Figure 1: The links between ecological character, ecosystem services and human well-being.

Healthy wetlands

‘Health’ is another way of describing the condition of the ‘whole’. 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 fish, a species of zooplankton or macroalgae, waterbirds, or humans, or to the nested tiers themselves, or even the landscape in which the wetland ecosystem is embedded. The phrase “healthy ecosystem” acknowledges that 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, construction or restoration. And the health of humans is in some way a reflection of the health of the ecosystem in which they live, or upon which they depend, and vice versa.
These views of reciprocity address any psychological discontinuity between humans (themselves) and the rest (their ‘environment’), where ‘nature’ is ‘other’ than culture, an increasingly discussed dysfunction in western thinking and rational policy-making that separates people or their institutions from nature (see Plumwood 1990, Berkes and Folke 2002).

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.

The relationship between biodiversity loss, ecosystem disruption and disease transmission may be instrumental in a search for indicators of the health of an ecosystem. There are well documented cases of disease emergence associated with land-use change, deforestation or other forms of ecosystem disruption, and global trends indicate this is increasing (Jones et al. 2008). Indeed both trade and intensive agriculture are known drivers of pathogen emergence and re-emergence through host switching and pathogen resistance to antimicrobial compounds. Biodiversity loss can increase disease transmission for important diseases associated with wetlands like malaria, West Nile virus and Schistosomiasis (Keesing et al. 2010 and references cited therein). The incidence rates of vector-mediated diseases and direct zoonoses have been proposed as a bioindicator for underlying disturbances to ecosystems (e.g. Cook et al. 2004), and notionally therefore its ‘health’. In a broader sense, aspects of animal and human health can become an important indicator for the health of an ecosystem, and vice versa, provided that there are clear causal links between the two.

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 might be derived from the claim that healthy ecosystems retain their vigour (productivity), their
resilience (capacity to recover from disturbance), and their organisation (their diversity and nature of interactions) (Rapport et al. 1998). In this way a claim to ‘healthy ecosystems’ comes from the explicit inclusion of the systems thinking required to make judgments on the desirability of an ecological character. It is also much more explicit about the health of components of the ecosystem (including humans).

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, rather than the relentless pursuit of some sort of stable state. This is consistent with the Ramsar Convention’s concept of wise use of wetlands and 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 (to include management objectives for particular uses of the wetland, and limits of acceptable change), to implement, monitor and respond accordingly, including interventions to restore particular features of the wetland where necessary (see Ramsar Convention 2008).

**Recognising wetland ecosystem services in public health**

Numerous examples can be drawn upon to show the link between ecological character and human health. A change in climate or hydrological regime, including precipitation, volumes and seasonality of surface water may decrease or elevate population numbers of vectors and alter rates of human exposure to pathogens (Lafferty 2009), as may changes to trophic structure of a wetland through over predation (Stauffer et al. 2006). Changing nutrient cycles and trophic status can lead to toxic algal blooms (Fristachi et al. 2008), and changing hydrological regimes can mobilise chemicals toxic to humans or agricultural products (Appleyard and Cook 2008, Harvey et al. 2002); land degradation and
declining productivity in wetland ecosystems can have direct or indirect health consequences for people whose livelihoods depend upon it (e.g. Béné and Friend 2009). In each case, wetland management must be involved in the intervention scenarios. Despite the abundance of evidence for these links, the contributions that a full range of ecosystem services for a particular ecosystem make to human health have rarely if ever been documented.

As shown in the MEA (2005, in its widely referred to Figure A), the linkages between broad categories of ecosystem services and components of human well-being, can be mediated by socioeconomic factors, and the strength of the linkages and the extent of the mediation can vary depending on the type of ecosystem and the geographical region. For example, a significant benefit will accrue for humans living in areas where soils have a high assimilatory capacity for pollutants, through the service of water filtration and purification; this service can be mediated strongly if economic conditions enable access to technologies for sanitation and reliable drinking water, or parts of the landscape where this service is enhanced.

If the capacity for socio-economic mediation is uneven between services and human well-being, then it is exacerbated by the degree of dependence on the services and the choices people have in and near wetlands. Some groups of people are more dependent on ecosystem services and the ramifications of their degradation can be shown to be immediate and direct, and sometimes reinforcing in a ‘vicious cycle’ (Butler and Oluoch-Kosura 2009), evident for those living in or near wetlands. In other instances people supplement livelihoods and incomes, and enrich lifestyles, from wetland ecosystem services thereby indirectly determining human health by contributing to other forms of well-being (like providing security, basic materials for good life, and for good social relations), and again these benefits are unequally shared in human populations. In short, exposure to harmful health effects from (insufficient) access to wetland ecosystem services is unequal. There will be different priorities for safeguarding the health of wetland communities in poor and rich countries, and differences in vulnerability between
wetland communities depending on their socio-economic status. “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 of Social Determinants of Health 2008).

Again, the consequence for wetland management is clear; wetland managers are required to help with interventions, and engage with those sectors that seek to address these determinants of health.

Health determinants in wetland settings

The linkage between ecosystem services, human health and their determinants, resonates with the Ottawa Charter for Health Promotion (World Health Organisation 1986) and more recently the Bangkok Charter (2006) which identified five major strategies for promoting health: building healthy public policy; creating supportive environments; strengthening community action; developing personal skills; and re-orienting health services. The central tenet was that “health is created and lived by people within the settings of their everyday life: where they learn, work, play and love”, establishing the healthy settings approach to health promotion: “…where people actively use and shape the environment and thus create or solve problems relating to health…” (WHO 1986). Examples of settings include schools, work sites, hospitals, villages and cities, and islands, but recently, and building on the work of Falkenmark and Folke (2002) and others, there has been a suggestion that watersheds, or water catchments, be considered a setting on the basis that this reconnects health promotion with the ecosystem context (Parkes and Horwitz, 2009, Parkes et al. 2010). One of the strengths of this proposal is that it explicitly puts ‘ecosystem’ into the parlance of public health, something that has been perceived to be missing from the healthy settings agenda. Another is that it foregrounds water as human society’s principal natural resource. We note here Strang’s (2005) description of the particular
qualities of water as one of two important ‘universalities’ (the other being the physiological and cognitive processes common to all human beings), that generate cross-cultural themes of meaning that persist over time and space, and Barbar’s (2007) idea of ‘water currency’. Furthermore, human health can be seen as commencing with the basic right to sufficient water for health and well-being\(^1\). Wetlands, as ‘the places of water’, conform to the construction of settings for health promotion, since they are normally identified as having physical boundaries, where a range of people have designated and defined roles around common meanings and values of water, where an organizational structure exists in the water resource and wetland management sectors, where health determinants and health inequalities can be addressed.

**Health issues in a wetland setting**

So far we have argued that *ecosystem services are provided in a wetland setting where determinants of human health exist*. The characteristic ways that wetland ecosystems and the services they provide, determine human health and well-being can be outlined:

1. **Contributors to hydration and safe 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, and they play a major role in treating and detoxifying a variety of waste products.

2. **Contributors to nutrition**: the world’s major food items, core requirements for human health, come from wetland ecosystems, and/or are irrigated by water 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. Inland fisheries and aquaculture contribute about 25% of the world’s production of fish. Wetland ecosystems also have a role in maintaining dietary diversity, contributing to a multi-

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\(^1\) In July 2010 the UN General Assembly formally recognised 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.
dimensional agenda focused on nutritional and health status, socio-cultural traditions, income
generation and biodiversity conservation.

3. Sites of exposure to pollution or toxicants: 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. These exposures result where ecosystem services have been eroded: principally when the
hydrological services that maintain biological, geological and chemical processes is distorted by human
activities of over extraction of water. Drainage of, and diversions of water are the two activities
responsible for the majority of such changes.

4. Sites of exposure to infectious diseases: Wetlands are the loci for communicable disease, where
microorganisms (the pathogens) are transmitted through water, people, animals as vectors, surfaces,
foods, sediments or air, any or all of which can be associated with wetlands. Poor quality water (as
unsafe water), inadequate sanitation and insufficient hygiene are the major risk factors for diarrhoeal
disease, which is the second leading contributor to global burden of disease (WHO 2010). An important
share of the total burden of disease worldwide could be prevented by improvements related to
drinking-water, sanitation, hygiene and water resource management. 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.

5. Settings for mental health and psychosocial well-being: Wetlands, in their myriad forms, become
embedded in the human psyche in formulations of “sense of place”. Changes to wetlands, to their
products, their ability to deliver a livelihood, or to become a source of toxic exposure or disease, can
influence a person’s mental health (Higginbotham et al. 2007). These potentialities are increasingly
recognized as being part of the wetland manager’s and public health practitioner’s spheres of
prevention and intervention (Tucker et al. 2006).
6. Places where people derive their livelihood: Addressing wetland management as if people’s lives, their livelihoods and their lifestyles depended upon it, will undoubtedly contribute to human health. Livelihoods comprise the capabilities, assets and activities to make a living. A wetland manager and a health service provider should seek to sustain the family and community livelihood in the context of the wetland, firstly by understanding the family and community situations by listening to their stories, hopes and wishes, and by acting according to them, within a context of local and traditional knowledge, government requirements, and market forces.

7. Places that enrich people’s lives, enable them to cope, and to help others: For those people who live in wetland settings, their different behaviours and activities will be a proximal determinant of their health. Lifestyle factors are related to the ecosystem services, particularly leisure, recreation, sporting activities, education, and cultural heritage (including a spiritual significance of water), provide for both physical and mental health given human affinities for wetlands and watercourses.

8. Sites of physical hazards: climate externalities like floods, severe storms, drought, and fire, and geological externalities like earthquakes and tsunamis, 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, infectious diseases, to physical injury and systemic chronic illness. The pathways to such disease events may be direct or indirect, and include 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 (Cook et al. 2008).

9. Sites were medicinal and other products can be derived: 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. 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 good example of the continued value of traditional knowledge to health care today.

These wetland ecosystem consequences for human health are shown together in Figure 2 in the form of layers, inspired by Barton and Grant’s (2006) determinants of health and well-being in our neighbourhoods, and Syme et al. (2008) ‘sphere of needs’ of water. Like the emphases in these other conceptual approaches, all of these features are cross-cutting and influence one another; what is proximal and distal can become causally connected.

*Figure 2: Influences on wetlands as settings for human health, showing the proximal factors of provisioning ecosystem services (food and water requirements), personal exposures and risks, and broader social determinants of health. Cross cutting mechanisms link all influences.*
A social ecology of health in a wetland setting

At first it might seem that what we have been arguing here, and what is argued elsewhere in vernacular like “healthy wetlands healthy people”, is a simple linear relationship where human health declines when ecosystem services are disrupted, and that human health improves so long as ecosystem services are maintained or enhanced.

A ‘double dividend’ (++) in Figure 3) 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, and 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 others, 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. 2005, 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, see also Table 2).
Figure 3. Four relationships possible when considering the condition of ecosystem services and human health.

However, it is erroneous to think that this relationship is as simple as the ++ or -- linearity; there are two other conceivable situations in the relationship. Firstly, analogous to the ‘environmentalist’s paradox’ (Raudesepp-Hearne et al. 2010), degraded ecosystem services can provide benefits to people in such a way that there are positive health outcomes (+ in Figure 3). Numerous examples exist, and three are given here:

Example 1. the application of DDT to wetlands, or their drainage, for malaria control (loss of supporting and regulating services of the wetland in order to decrease infection rates); Example 2. conversion of a wetland into a reservoir (loss of regulating services of 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, as pointed out by Corvalan et al. (2005), maintained or enhanced ecosystem services can have problematic consequences for human well-being (+- in Figure 3), and again numerous examples exist: **Example 1.** urban wetlands protected for nature conservation (with protection to supporting and regulating ecosystem services) can also support the presence of mosquitoes and other vectors and in so doing expose humans to vector-borne diseases (see Malan et al. 2009); **Example 2.** the presence of large woody debris in rivers (regulating services, slowing down water flows, contribution to the trophic web as supporting service) is an occupational and recreational hazard for swimming or boating and may even lead to loss of life.

In addition, the four views in Figure 3 still greatly oversimplify the relationship. In any wetland ecosystem, on balance, some ecosystem services will be maintained, some enhanced and some degraded; likewise there will always be poor health outcomes, and some in the population will always received improved health. And if the ecosystem services and health outcomes happened to be causally linked, the situation can be complex and layered, 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, and alter local and regional climates, potentially affecting disease vector distributions and hence disease patterns over time. Food security might link to any or all of water quality, household income, plant genetic resources and fisheries management.

These causal chains and linkages are often important and complex and imply that trade-offs between benefits will occur when wetlands are developed or otherwise altered to promote or favour one or a few services over others (Nelson et al. 2008, Gordon et al. 2010), and equally when particular health outcomes occur when others are possible.
Decisions that lead to the (over)use of groundwater 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 hydration, 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 problematic for human health. All four quadrants of Figure 3 can be filled. So if water use is allowed knowingly, this represents a trade-off scenario: one set of ecosystem services for another, and one set of human health outcomes for another.

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

**Health Impact Assessments for negotiating ecosystem services trade-offs**

Like others (see Campbell et al. 2010) we acknowledge that recognising trade-offs is no simple matter because a trade-off perceived by one stakeholder may not be recognized by another. So undertaking a process by which the trade-offs and their consequences are fairly 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. We perceive two areas around which trade-offs need to be negotiated; valuation of ecosystem services and the human health consequences of intervention (or non-intervention).

Seen as its crudest dysfunction, 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 are negotiating these
trade-offs. This is largely attributed to 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; however, 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).

Human health issues will always present another dimension and there are key questions for wetland managers here: what will be the human health consequences of intervening for wetland management? How do we intervene to improve human health itself? Some of the key approaches, tools and instruments likely to be used by the health sector to respond to such questions should be understood and used by wetland managers. Monitoring, surveillance and intervention, burden-of-disease assessments (BDA), health impact assessments (HIA), risk assessments, community and stakeholder engagement, are commonly used, and in general structure they might be similar to their environmental equivalent. Their focus will, however, be different; it will be important for these instruments and approaches to be developed for use by wetland managers.

For wetland management the four types of health impact assessments proposed by Harris-Roxas and Harris (2010) will be useful in different circumstances; a mandated HIA will be done to meet a regulatory or statutory requirement; a decision support HIA, done voluntarily with the goal of improving decision-making and implementation; an advocacy HIA conducted by local organizations or groups seeking to
influence decision-making and implementation; and community-led HIA where potentially affected communities can examine issues or proposals that are of concern for their health consequences.

Regarding HIA and trade-offs, Birley (2002) identified the need to know how to use health-impact assessments within the broader context of economic appraisal structure; he proposed a framework that associated health determinants with five forms of capital in relation to rural development. Table 2 extends this concept for wetlands, relating the classes of health requirements, consequences and determinants associated with wetlands, and for each the relevant ecosystem services as a way of incorporating wetland valuation in the assessment. Evidence for how health can be positively or negatively influenced according to these ecosystem services can then be expounded for the wetland in question. Such an approach concurs with the call by Krieger et al. (2010) for the broadening of HIA beyond the social determinants of health and into the domains of housing, water, sanitation, transport and communication, in so doing also appealing to private industrial corporations and major financial institutions, when matters of resource use and human health are of paramount importance.

Conclusion

We note 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 (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 describing the benefits of maintaining healthy ecosystems. As a consequence there is less information covering the benefits for human health from wetland ecosystem services.

We have therefore sought to provide a strategy for collecting further information and teasing apart the inter-relationships between wetlands and human health. This was done by providing a joined-up
account, by adopting constructs from ecosystem management, ecological economics, public health, epidemiology and health promotion. We summarise an accepted global framework for describing a wetland’s ecological character and describe how it includes the services that wetlands provide to human welfare. We make a case for foregrounding wetland ecosystems as the settings and context in which health determinants can be addressed. We outline nine ecosystem consequences for human health in wetland settings that can be used as an analytical checklist.

1. **Contributors to hydration and safe water;**
2. **Contributors to nutrition;**
3. **Sites of exposure to pollution or toxicants;**
4. **Sites of exposure to infectious diseases;**
5. **Settings for mental health and psychosocial well-being;**
6. **Places where people derive their livelihood;**
7. **Places that enrich people’s lives, enable them to cope, and to help others;**
8. **Sites of physical hazards;** and
9. **Sites were medicinal and other products can be derived.**

And finally we demonstrate the utility of health impact assessment as an instrument to integrate these constructs. Together these steps provide a strategy which will allow the trade-offs that exist between sets of ecosystem services and different health outcomes, to be evaluated, and the sociopolitical mechanisms that support them to be accountable.
References


Economics 35: 7-23.


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

* Ecosystem Services are categorised as “provisioning” (P), “regulating” (R), cultural (C) or “supporting” (S) according to the categorization in the Millennium Ecosystem Assessment. Some may appear in the “processes” section as well as the “services” section above.

# For nature conservation value as an ecosystem ‘service’ (S)*, see items under ‘components’ and ‘processes’
Table 2: Major classes of health issues as they relate to wetland ecosystems, showing for each the ecosystem services (drawn from Table 1) that are of principal interest, or those that have consequences for human health when disrupted.

<table>
<thead>
<tr>
<th>Health: core requirements</th>
<th>Relevant wetland ecosystem services</th>
<th>Health effects, health outcomes from ecosystem services</th>
<th>Examples of disruptions to wetland ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to sufficient water</td>
<td>Drinking water for humans /livestock Groundwater replenishment Water purification/ waste treatment or dilution Flood control, flood storage</td>
<td>Adequate water availability to meet human needs Good hygiene</td>
<td>Depletion of water from drainage or over-extraction Loss of access to water (contamination) Non-renewal of water due to decline in rainfall.</td>
</tr>
<tr>
<td>Access to sufficient nutrition</td>
<td>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 and nutrient retention</td>
<td>Good nutrition, growth and development Appropriate diet (including essential vitamins and trace elements) and appropriate behaviour associated with a healthy diet (i.e. physical exercise)</td>
<td>Overextraction of water for irrigation Overharvesting of wetland produce and Over application of pesticides Loss of genetic diversity/ variety and simplification of wetland trophic webs as a result)</td>
</tr>
<tr>
<td>Health risk: Exposures</td>
<td>Relevant wetland ecosystem services</td>
<td>Health effects, health outcomes from ecosystem services</td>
<td>Disruptions to wetland ecosystems (examples)</td>
</tr>
<tr>
<td>Exposure to pollution</td>
<td>Water purification/waste treatment or dilution Other hydrological services: hydrological maintenance of biogeochemical processes Soil, sediment and nutrient retention</td>
<td>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.</td>
<td>Exposure to: Soil or water-borne inorganic chemicals Soil or water-borne microbial toxins Atmospheric particles or chemicals</td>
</tr>
<tr>
<td>Exposure to Infection</td>
<td>Drinking water for humans and/or livestock Water purification/ waste treatment or dilution Biological control agents for pests/diseases</td>
<td>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.</td>
<td>Water-borne diseases Vector-borne diseases Emerging infectious diseases Antimicrobial resistance</td>
</tr>
<tr>
<td>Exposure to psycho-social stresses</td>
<td>Contemporary cultural significance, including for arts, creative inspiration, and existence values</td>
<td>Meaningful interactions with wetland ecosystems as places; enhanced abilities to derive benefits from cultural services</td>
<td>Depression, suicide (associated with hopelessness and helplessness of wetland degradation and other environmental change; and their social consequences) Grieving over loss of place (“Solastalgia”)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exposure to physical hazards</td>
<td>Climate regulation Flood control, flood storage Soil, sediment and nutrient retention Coastal shoreline and river bank stabilization and storm protection Local climate regulation/buffering of change</td>
<td>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 this table, associated with enhanced livelihoods from wetland ecosystems</td>
<td>Exposure to extremes of temperature Exposure to floods and droughts, cyclones, hurricanes, tsunamis etc. Any risk of exposure (as described in this paper) where change to a wetland ecosystem has been implicated</td>
</tr>
</tbody>
</table>

### Social Determinants of Health

#### Examples of wetland ecosystem services

<table>
<thead>
<tr>
<th>Benefits if services are maintained or enhanced</th>
<th>Consequences of disruption to the services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced work-place, occupational exposures</td>
<td>Work-place, occupational exposures</td>
</tr>
<tr>
<td>Sufficient water and food</td>
<td>Insufficient water, insufficient nutrition, exposure to toxics, diseases and psychological stresses associated with loss of livelihoods from change to a wetland ecosystem</td>
</tr>
<tr>
<td>Sustained living made from wetland assets</td>
<td>Overextraction of water Overharvesting of foods</td>
</tr>
</tbody>
</table>

#### Livelihoods

- Water purification/waste treatment or dilution
- Most provisioning services
- All cultural services

#### Lifestyles (and personal behaviours)

- Recreational hunting and fishing
- Water sports
- Nature study pursuits
- Educational values
- Understanding ecosystem behaviour
- Cultural heritage
- Contemporary cultural significance, including for arts and creative inspiration, and 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 and 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 an alienation from culturally significant elements of wetland ecosystems |

#### Examples of disruptions to wetland ecosystems

- Overextraction of water
- Overharvesting of foods
- Both impacting on individuals dependent on them for their livelihoods.

### Health effects, health outcomes from ecosystem services

- Reduced work-place, occupational exposures
- Sufficient water and 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.