Wetlands as Settings for Human Health —the Benefits and the Paradox

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Abstract As wetlands provide many valuable ecosystem services and are amongst the most degraded ecosystems globally, further degradation could greatly affect the well-being and health of people dependent on them. Healthy wetlands are generally associated with enhanced ecosystem services and improved outcomes for human health, and unhealthy wetlands with degraded ecosystem services and poor outcomes for human health. However, the relationships can also be paradoxical with some direct benefits for human health leading to the loss of other ecosystem services, in particular regulating and supporting services, and the enhancement of others, leading to poor outcomes for human health. This results in a health paradox whereby there is a loss of regulating and supporting services from steps to enhance human health. Examples of the health paradox include: drainage of wetlands for malaria control; conversion of a wetland into a reservoir to store water for human consumption and irrigation; and regulation of rivers for flood mitigation activities to alleviate loss of life or property. A wetland paradox also occurs when there are poor outcomes for human health as a consequence of the maintenance or enhancement of ecosystem services. Examples of the wetland paradox includes: urban wetlands protected for nature conservation can also support mosquitoes and other vectors, and expose humans to vector-borne diseases; and the maintenance of large woody debris in rivers which slows down water flows, and contributes to the trophic web and is a recreational hazard for swimming or boating. In response a framework for the conceptualisation of human and wetland relationships, including the paradoxical situations has been provided based on the concept of wetlands as settings for human health. This enables the trade-offs that have and will occur between wetland ecosystem services and human health to be addressed.

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Introduction

The complexities of the interactions that occur between people and wetlands has been addressed more and more in recent years, for example, through global assessments of water, biodiversity and the wider environment (Falkenmark et al. 2007; Arthurton et al. 2007; Gordon et al. 2010; Armenteras and Finlayson 2011). These assessments, largely following the lead of the Millennium Ecosystem Assessment (MEA 2005), have focused on the benefits that can accrue by promoting the positive relationships that can exist between human well-being and livelihoods, as expressed through the Millennium Development Goals, and wetlands. That is, they have focussed on wetlands as settings for human well-being, including human health and livelihoods, through the provision of ecosystem services, encompassing provisioning, regulating, supporting and cultural services (as defined by the MEA 2005) as well as settings for biodiversity conservation.

At the same time these assessments have provided further documentation that wetlands and wetland-dependent species are in severe decline globally, as are the many ecosystem services that they provide for many people. Given projected increases in the demand for food and fresh water it is expected that wetlands will face increased pressures and further decline in the benefits that they provide for large numbers of people, in particular for those people who depend most directly on wetlands for their sustenance and well-being (Falkenmark et al. 2007; Gordon et al. 2010). Wider recognition that wetlands are important settings for human well-being and for biodiversity conservation is seen as an important step if the decline of biodiversity and ecosystem services from wetlands is to be stopped, let alone reversed (Horwitz and Finlayson 2011). The latter is important—global efforts to reverse the decline of wetlands and wetland species have not kept pace with the rate of decline (MEA 2005; Armenteras and Finlayson 2011). In other words, despite the problems being articulated for several decades (MEA 2005) the responses to the loss of biodiversity and ecosystem services have been inadequate to halt the decline. Further, efforts to ensure greater equity in access to and sharing of the benefits that accrue from biodiversity are increasingly seen as important steps in changing this situation (Armenteras and Finlayson 2011).

The complexities of the relationships between wetlands and people are explored in this book through a general treatment of ecology-health issues for both the wetland and public health sectors, in recognition that both sectors have a vital role to play in ensuring the maintenance of the benefits provided by healthy wetlands. The corollary, namely that disrupting the provision of ecosystem services has adverse impacts on human health, is also examined as a prelude to examining ways in which multi-disciplinary research and practice (including community participation) can be

enhanced and policies generated to support ecosystem and human health concurrently.

A key premise behind the abovementioned intent is that the environmental health problems of the twenty-first Century cannot be addressed by the traditional tools of ecologists or epidemiologists working in their respective disciplinary silos; this is clear from the emergence and re-emergence of public health and human well-being problems such as cholera pandemics and mosquito borne disease, as well as the impact of climate change and episodic events and disasters (e.g. hurricanes). The Millennium Ecosystem Assessment concluded that genuine cross-disciplinary approaches were necessary to tackle these problems (MEA 2005), a theme subsequently taken up syntheses provided in the Global Environment Outlook (UNEP 2007, 2011). This book brings the disciplines of ecology and health sciences closer to such a synthesis for researchers, teachers and policy makers interested in or needing information to manage wetlands and their interconnected human health and well-being issues.

While recent global assessments and syntheses provide a basis for many of the technical concepts covering health and wetlands that are expanded in the book, they do not, on the whole, explore the technical knowledge and information that supports the intricacies of the interactions between components of the wetlands and people. Similarly, the major text books covering wetland ecology focus on the science of wetland populations and ecological processes and not on human health issues, responses or specific interactions between wetlands and people. This book brings the disciplines of ecology and health sciences closer together with a synthesis for researchers, teachers and policy makers of the relationships that exist between wetlands and human health—relationships that are fundamental to a sustainable future, but also contains what we have termed a health paradox and a wetland (environment) paradox (Horwitz and Finlayson 2011).

The Human-Wetland Nexus

The relationships between humans and wetland ecosystems go back many millennia with hunter-gatherers being directly dependent on the availability of resources in the immediate environment, foremost being a reliable and clean source of drinking water, but also for food and materials for making tools, shelter, and for fuel for heating and cooking (Junk 2002; Gopal et al. 2008). Over many years and in many places, people developed agriculture, including increasingly intensive use of wetlands for grazing, cropping and horticulture, and eventually changed the manner in which wetlands were managed, including the spread of wide-scale detriment, largely through the expansion of agriculture (Finlayson et al. 2005), but still with a large dependency on the provision of ecosystem services (Falkenmark et al. 2007; Gordon et al. 2010). The continued importance of agriculture in wetlands is evident from analyses of the extent of agriculture in wetlands listed as internationally important under the Ramsar Convention (Ramsar sites); for example, in 2006

some 78 % of Ramsar sites globally were found to support some form of agriculture (Rebelo et al. 2009a), and similarly, in 2008 some 93 % of Ramsar sites in sub-Saharan Africa supported agriculture (Rebelo et al. 2009b).

Unfortunately, the increasing extent of human exploitation and modification of the environment has also adversely affected the health of wetlands, some of which have been lost or degraded to an extent whereby they no longer provide the ecosystem services that previously supported human well-being and health (Revenga et al. 2000; Agardy and Alder 2005; Finlayson and D'Cruz 2005). Sources of drinking and irrigation water have dried, leading to thirst, starvation and population displacement; toxic pollutants have poisoned waters, fish and people; alterations to water regimes and vegetation structures have led to hardship, epidemics, and wide-spread environmental degradation and adverse consequences for people (Horwitz et al. 2012).

On the other hand, changes in land cover and land use to accommodate expanding agriculture and industrial development have had many beneficial outcomes for many people, for example, through increased irrigation and food production. Unfortunately, many agricultural systems 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 sustainability (Molden et al. 2007). The consequences of such approaches include the loss of provisioning services such as fisheries, loss of regulating services such as storm protection and nutrient retention, with negative feedback on food and fibre production. Human health has also suffered in a direct sense, for example, through the increased prevalence of insect-borne disease or through changes in diet and nutrition or the loss of regulating services, such as erosion control and the amelioration of floods (Corvalan et al. 2005). People in rural areas who use a variety of ecosystem services directly for their livelihoods are likely to be the most vulnerable to such changes in ecosystems (MEA 2005).

Finlayson et al. (2005) 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. The first United Nations World Water Development Report noted that a healthy and unpolluted natural environment was essential for human well-being and sustainable development, and further stressed that wetland (aquatic) ecosystems and their dependent species provided a valuable and irreplaceable resource base that helped to meet a multitude of human and ecosystem needs which are essential for poverty alleviation and socio-economic development (UN-WWAP 2003). The report also noted that human health provided one of the most striking features of the link between water and poverty.

The adverse consequences of increased interactions between people and wetland ecosystems have received more attention in recent years with the Millennium Ecosystem Assessment (MEA 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 health and human health concurrently. Almost in parallel it has become apparent that many environmental health problems cannot be solved by 'traditional' health approaches alone. Rather, broader approaches are needed to analyse interactions between humans and the surrounding environment (Corvalon et al. 2005), often drawing on a wider scientific base, including ecological and social sciences, and accepting that humans are not separable from the complex vagaries of the natural environment.

A fundamental and underlying part of this complexity is the paradox that healthy wetlands (*sensu* Ramsar Wetlands Convention; Finlayson and Weinstein 2008) can provide many valuable ecosystem services as well as support vectors for water-borne diseases (Corvalon et al. 2005). The complexity of such relationships is shown by the historical links between malaria and humans in parts of Europe (O'Sullivan et al. 2008). If wetland health 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 changes in wetland health. 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 health and human health and the ecology of the vectors and diseases. The interactions and reciprocity of the complex 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 (Mojola 2009).

As wetlands provide many valuable ecosystem services and are amongst the most degraded ecosystems globally, further degradation could greatly affect the well-being and health of people dependent on them both directly and indirectly. In response, the Ramsar Wetland Convention has placed more attention on developing the scientific concepts behind the metaphor 'healthy wetlands, healthy people' and sought more understanding of how people and wetlands interact, for example, through analyses of the interactions between agriculture and wetlands (Falkenmark et al. 2007; Wood and van Halsema 2008) and fisheries and wetlands (Kura et al. 2004), and in this instance, the interactions between human health and wetlands (Horwitz et al. 2012). The metaphor 'healthy wetlands, healthy people' 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 (MEA 2005) and subsequent global assessments that have addressed human well-being and ecosystem services (Molden et al. 2007; UN-WWAP 2006; UNEP 2007). The interactions between human health and wetlands are expanded in this book through an examination of the linkages between human health and ecosystem services obtained from wetlands; the emphasis being on human health as a component of human well-being and linked inextricably with wetland health.

Wetlands as Settings for Human Health

With this background the purpose of the book is to review and map out the relationships and issues concerning the wise use of wetland ecosystems and human health, including information and concepts from the Millennium Ecosystem Assessment and its synthesis reports (www.millenniumassessment.org). Specific issues that have been addressed include:

- wetland health and ecological character of wetlands;
- human health and wetland ecosystem services;
- the effects on human health of disruptions to wetland ecosystem services;
- economic values and incentives for supporting human health;
- global trends affecting wetlands and human health; and
- responses and interventions for maintaining the ecological character of wetlands and supporting human health.

In addressing these issues the trade-offs between ecosystem maintenance and the risk of human diseases and ill-health have been considered with comments provided on the complexity of making decisions and choices that support ecosystems and the services that they provide. In doing this the following issues have been addressed—declines in water quantity and quality, including waterborne pollutants; human sanitation; water-related diseases; disease emergence related to small and large dams; increased land use in marginal landscapes leading to closer disease contacts; implications of climate change for human health issues associated with wetlands; human nutrition and wetlands; and wetlands as sources of beneficial drugs. A further section is added on the effect of global trends on wetlands and human health with attention being drawn to the complex interactions with global climate change.

The depth and detail of coverage of the above have benefited by the accessibility of information in recent global overviews such as the Millennium Ecosystem Assessment (MEA 2005), the World Water Development Report (UN-WWAP 2003, 2006), the Comprehensive Assessment of Water Management in Agriculture (Molden 2007), and the Global Environmental Outlook (UNEP 2007, 2011). These overviews 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 the achievement of the Millennium Development Goals that may run counter to efforts focussed on wetland conservation with an emphasis on the biodiversity in virtual isolation of wider ecosystem issues. 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 health and human health concurrently (Finlayson et al. 2005). It is contended that at a metaphorical level the linkages are being established—further scientific evidence is needed to support these and enable more informed decisions that consider the complexities involved.

The importance of wetlands for humans, in particular in relation to their health and well-being was explored by Horwitz et al. (2012) in a landmark report that

considered wetlands as settings that supported and even determined human health and well-being in a number of ways, including the provision of safe water and food and support for livelihoods, but also as places where people could be exposed to pollution, toxicants or infectious diseases. They concluded that wetland settings could "… *either enhance or diminish human health depending on the ecological functioning of wetlands and their ability to provide ecosystem services*." and that wetland loss and degradation would have consequences for human health, and that adverse outcomes were likely to be distributed unequally, possibly along socio-economic lines.

Horwitz and Finlayson (2011) further explored the concept of wetlands as settings for human health by considering the commonality of issues contained within the concepts of the ecological character of wetlands and wetland ecosystem services. They explored the modern tendency to assess the condition of wetlands and wetland resources separately from human well-being associated with wetlands (considering wetlands in the broad sense of the word as defined by the Ramsar Convention on Wetlands in 1971, to include, e.g., rivers, lakes, marshes, rice fields, coastal areas), and developed the synergies with the Ramsar Convention's concepts of the wise use of wetlands and the maintenance of their ecological character. The Convention responded to the widening gap between wetland conservation and the use of wetlands by people by equating the terms *wise use* and *ecological character* with the maintenance of ecosystem services. This was done by adopting the framework developed by the Millennium Ecosystem Assessment as a framework for the wise use of wetlands (Fig. 1) and updating the definitions of wise use and ecological character (Ramsar Convention Secretariat 2010; Davidson and Finlayson 2007; Finlayson et al. 2011).

> *Ecological character* is defined as "the combination of the ecosystem components, processes, and benefits or services that characterize the wetland at a given point in time.
> *Wise use* of wetlands is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development."

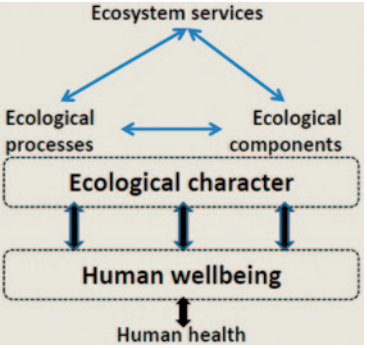

Fig. 1 Conceptualisation of the linkage between ecological character (comprising ecological processes and components and ecosystem services, and their interactions) and human health (comprising human health as one constituent)

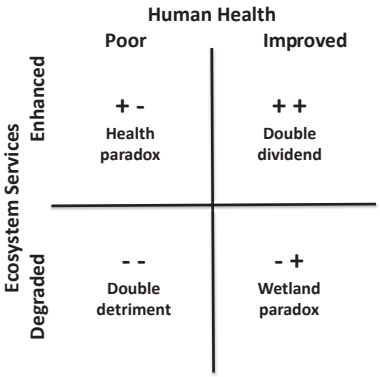

Fig. 2 Categorisation of the settings for wetland and human health based on the condition of ecosystem services and outcomes for human health (adapted from Horwitz and Finlayson 2011). The four settings are: the "*double dividend*" (++) with healthy wetlands and enhanced ecosystem services and improved outcomes for human health; the "*double detriment*" (−−) with unhealthy wetlands and degraded ecosystem services and poor outcomes for human health; the "*health paradox*" (+−) with the loss of regulating and supporting services from steps to enhance human health through; and the "*wetland paradox*" (−+) with poor outcomes for human health as a consequence of the maintenance or enhancement of ecosystem services

The description of the ecological character of a wetland provides a basis for identifying key issues for management, including the role of wetlands in supporting human well-being and health (Fig. 2). It also enabled the relationship between human well-being and health to be expressed pictorially. In making these connections human well-being is treated as a broad notion that includes security, basic materials for a good life, health, good social relations, and freedom of choice and action (MEA 2005), and where *human health* is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO 2006). This illustrates how the Ramsar Convention has linked human health with the ecological character of wetlands and given support to the metaphor of "healthy wetlands, healthy people" as a central tenet of the international efforts to make wise use of wetlands globally.

With the above described background it is possible to depict human health issues in a wetland setting, with Horwitz and Finlayson (2011) identifying the following as ways in which wetlands affect human health and well-being. Namely, wetlands are:

- contributors to hydration and safe water;
- contributors to nutrition;
- sites of exposure to pollution and toxicants;
- sites of exposure to infectious diseases;
- settings for mental health and psychological well-being;
- places where people derive their livelihoods;
- places that enrich people's lives, enable them to cope, and allow them to help others;

- places that help absorb the damage of natural disasters; and
- sites where medicinal and other products can be derived.

The relationships that exist between healthy wetlands and the provision of ecosystem services that provide benefits for human health are complicated and include direct or linear links as well as indirect links. Examples of direct links include the provision of food, fuel and fresh water, whereas indirect links include the reduction in vulnerability to extreme events, such as storms and floods, or the amelioration of climate change through carbon sequestration. When wetlands are disrupted these benefits are generally assumed to be reduced or lost; however, the relationship between ecosystem services and human health and wetland health is more complex. In some circumstances degraded wetlands can provide benefits for human health, as shown in the simplified categories outlined in Fig. 2.

The generalised relationships between ecosystem services and human health are outlined in Fig. 2. Healthy wetlands are generally associated with enhanced ecosystem services and improved outcomes for human health (the ++ or double dividend scenario), and unhealthy wetlands with degraded ecosystem services and poor outcomes for human health (the −− or double detriment scenario). However, given the multiplicity of ecosystem services and outcomes for human health, the relationships can also be paradoxical with some direct benefits for human health leading to the loss of [other] ecosystem services, in particular regulating and supporting services, and the enhancement of others, for example, nature conservation in particular environments, leading to poor outcomes for human health. These situations lead to what is described as the "health paradox" (the +− scenario) and the "wetland paradox" (the −+ scenario) in Fig. 2.

The health paradox occurs when there is a loss of regulating and supporting services from steps to enhance human health through, for example: (i) drainage of wetlands for malaria control; (ii) conversion of a wetland into a reservoir to store water for human consumption and irrigation; and (iii) regulation of rivers for flood mitigation activities to alleviate loss of life or property. The wetland paradox occurs when there are poor outcomes for human health as a consequence of the maintenance or enhancement of ecosystem services, for example: (i) urban wetlands protected for nature conservation can also support mosquitoes and other vectors, and expose humans to vector-borne diseases; and (ii) the maintenance of large woody debris in rivers which slows down water flows, and contributes to the trophic web and is a recreational hazard for swimming or boating.

While the scenarios in Fig. 2 simplify the interactions between human and wetland health they do provide a framework for considering the general relationships or settings for these relationships. Horwitz and Finlayson (2011) explain that the simplification is to some extent inevitable given that in any wetland some ecosystem services will be maintained, some embellished and some degraded, and similarly, there is the ever present likelihood that there will be both poor and beneficial health outcomes for various people. The multiplicity of wetland and human health outcomes can seem complex but through careful consideration many can be seen to be causally linked, layered, displaced in space and time, dependent on similar or even the same modifying forces, and form chains of events and outcomes.

The chains of events and outcomes imply that trade-offs for particular aspects of human health will occur when wetlands are modified by human activities that promote or favour one or a few ecosystem services over others. In saying this we note that a comprehensive and specific assessment of how particular wetland ecosystem services, or combinations of services, affect human health has not been undertaken.

Horwitz and Finlayson (2011) have provided a framework for collecting further information and teasing apart the relationships between wetlands and human health. This was developed by providing a joined-up account and by adopting constructs from ecosystem management, ecological economics, public health, epidemiology, and health promotion. They also drew upon an accepted global framework for describing a wetland's ecological character and described how it should include the services that wetlands provide to human welfare. In doing this they made a case for bringing wetland ecosystems to the foreground as the settings and context in which health determinants can be addressed.

The complexities of interactions between wetlands and human health are contained within the conceptualisation of wetlands as settings for human health, including those of a paradoxical nature. The framework for the conceptualisation does not ignore the paradoxes—rather it enables them to be highlighted along with the double dividend and double detriment scenario. This includes what have been termed the "health and wetland paradoxes": (i) the health paradox occurring when there is a loss of regulating and supporting services from steps to enhance human health, and (ii) the wetland paradox occurring when there are poor outcomes for human health as a consequence of the maintenance or enhancement of specific ecosystem services.

Establishing the trade-offs that have and will occur between multiple measures of wetland ecosystem services and multiple measures of human health can be done using the concept of wetlands as settings for human health. The alternative of treating them separately, as has been done in many societies for decades (or longer), may drive us further towards the double detriment rather than towards the double dividend scenario. Looking at wetlands and human health in this manner also enables a further statement about the situation whereby wetlands are seen as valuable, and yet are highly degraded by human activities. The settings concept raises the hypothesis that insufficient attention has been given to the dividends for human health that can accrue from a healthy wetland, and conversely, that more attention has been given to the negative outcomes that can accrue from an unhealthy wetland. Further, it may also be hypothesised that the consequences of the health paradox has received more attention than the consequences of the wetland paradox.

The settings construction enables the complexities of the interactions between wetlands and human health to be explored in a manner than extends far beyond the oversimplification of statements such as "healthy wetlands healthy people". The construction of artificial wetlands in urban environments is an example where wetland settings are considered to bring multiple benefits to people, including, in places, the treatment of wastewater and mediation of flood flows while providing amenity value for people. In many instances however, artificial wetlands are constructed for single purposes, with Everard et al. (2012) describing them as nature

without imagination. The restoration of wetlands, as actively promoted by the Ramsar Convention (Alexander et al. 2011; Alexander and McInnes 2012), provides another opportunity to develop the benefits of wetlands as settings for human health and well-being. Recent attention to the creation or restoration of urban wetlands is an area where the concept of wetlands as settings with potentially paradoxical outcomes is most advanced.

The complexities of human interactions with wetlands in urban areas are being explored with increasing attention to the benefits and problems that may arise when wetlands are created, highly modified or restored (McInnes 2014). The same viewpoint may not be as prevalent in more rural settings with smaller populations, such as in the Murray-Darling Basin in south-eastern Australia, where steps to restore the riverine environment have focussed largely on engineering solutions based on hydrological criteria with little consideration of wider values and benefits for people (Pittock and Finlayson 2011). The conceptualisation of wetlands as settings for human health and well-being, taking into account the double dividend and paradox, as described above, is seen as a way of exploring the benefits that can accrue for people from wetlands.

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