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Water for nature; sustainable solution or long-term liability?

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Introduction

The Brundtland Report in 1987, *Our Common Future,* and UNCED Conference in Rio in 1992 marked a turning point in modern thinking. A central principle of Agenda 21 and of *Caring for the Earth* (IUCN/UNEP/WWF, 1991) is that the lives of people and the environment are profoundly inter-linked. Ecological processes keep the planet fit for life providing our food, air to breathe, medicines and much of what we call "quality of life" (Acreman, 1998). The immense biological, chemical and physical diversity of the Earth forms the essential building blocks of the ecosystem and every form of life is unique and warrants respect, regardless of its direct worth to humankind. The lasting benefits of nature depend on maintenance of essential ecological processes and life-support systems and upon the diversity of life forms (McNeeley *et al.,* 1990). Maintenance of our planet's ecosystem depends on many factors, particularly energy and nutrients, but water is also essential to all life. Humans use water directly for domestic needs, growing food, generating power and for industrial processes. People also use water indirectly by benefiting from valuable products (e.g. fish), and services (e.g. water regulation) provided by aquatic ecosystems. Additionally, it satisfies the growing belief amongst many people that humans have a moral duty to protect biodiversity, through providing sufficient water to maintain flora and fauna (Acreman, 2001). Thus, whilst people need access to water directly to drink, providing water to the environment means using water indirectly for people. Costanza *et al.* (1997) calculated the economic value of 17 ecosystem services for 16 biomes and derived a figure of US$ 16-54 trillion per year (with an average of US$33 trillion per year) for the value of the entire biosphere. This is almost twice the global national product total of US$18 trillion. To implement this concept, the declaration from the Second World Water Forum in The Hague 2000 and Johannesburg 2005 summits highlighted the need to ensure the integrity of ecosystems through sustainable water resources management.

Limitations to sustainable water management

Achieving sustainable water management to conserve ecosystem functions and services requires a number of inter-related elements, including political will, supporting legislation, well-functioning institutions and sound scientific understanding. A major problem is that in most countries not all these elements are in place. Pioneering radical legislation was developed in South Africa, whose Water Law (Rowlston and Palmer, 2002) states that: "the quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems". Based on the same concept, the Water Framework Directive of the European Union requires member states to achieve good ecological status in all water bodies (European Commission, 2000). Other countries, such as Tanzania (MWLD, 2001) have followed this example with similar water policies and laws, but they currently lack the institutional capacity to implement them.

In an ideal world, the development of laws and policies is based on sound scientific understanding. In reality, science is often driven by the need to implement existing laws. South Africa, USA, Australia and western European countries have led development of the science of environmental flows that has been produced methods to define water needs of aquatic ecosystems (Acreman and Dunbar, 2004). However, scientific understanding of ecosystem processes remains poor and the reality of many management concepts, such as minimum flow thresholds, are still subject to debate (Acreman, 2005). As a result, implementation of laws and policies to conserve aquatic ecosystems is based on incomplete knowledge. For example, the European Water Framework Directive requires the setting of environmental standards that define the maximum amount of water that can be abstracted without degrading a river ecosystem. Such standards have been set for UK rivers (Acreman *et al*., 2006a) on the basis of expert opinion which extrapolates the knowledge of river scientists beyond the bounds of which many feel comfortable. Many methods used to inform major decisions about environmental flows are developed with politically driven time constraints, such as the Murray Flow Assessment Tool used by the Murray Darling Basin Commission in Australia (Davis and Acreman, 2003), and are often limited in their representation of ecological or hydrological processes.

Wetland functions

Wetlands provide an example of the mis-match between scientific understanding and the development of laws and policies to protect ecosystem functions. The terms wetlands encompasses a wide range of eco-types including Pantanal in South America, the Okavango swamps in southern Africa, the inner Niger delta of west Africa, the Indus delta in Pakistan, the peat swamps of Indonesia and the billabongs of south-east Australia. Wetlands support ecosystems of immense productivity and biodiversity including over 10,000 species of fish and over 4,000 of amphibians. In addition, as water moves into and out of wetlands hydrological and hydro-chemical changes take place, which give rise to hydrological functions. For example, flood water storage on floodplain wetlands of the Charles River, USA (Sather and Smith, 1984) reduces flood risk downstream, the Nakivubo swamp in Uganda removes much of the nutrient load of sewage from Kampala (Kansiime and Nalubega, 1999) and inundation of Hadejia-Nguru wetlands of northern Nigeria recharges the regional groundwater aquifer (Hollis *et al*., 1993).

One of the first assessments that recognised the hydrological functions of wetlands was undertaken by Adamus and Stockwell (1985) using studies from the USA. However, global appreciation of wetlands is largely due to IUCN, who published a list of potential wetland functions with worldwide examples (Dugan, 1990). This work stimulated the publication of numerous other documents (e.g. Davis and Claridge, 1993; Commission of the European Communities, 1995; OECD, 1996) that proposed wetlands as a sustainable solution to many river basin management issues, including flood risk, water supply and effluent disposal. The success of the awareness raising is demonstrated by the resulting wetland legislation around the world such as the protection of dambos in Zimbabwe to conserve their water regulation function. Many engineers were sceptical of the all-embracing claims of a largely ecologically-based wetland lobby, which led to wide-spread dismissal of the true wetland benefits. This was due partly to mis-interpretation of Dugan's list of *potential* functions, with many readers assuming that all wetland performed all functions in all circumstances. Lack of detailed scientific knowledge had precluded IUCN from more detailed explanation of precisely which functions applied to which wetlands.

Bullock and Acreman (2003) undertook a comprehensive review of 169 published papers on wetland research to produce a firmer scientific base to hydrological functions. They concluded that wetlands are significant in altering the water cycle; of the 439 statements found relating to hydrological functions, only 83 (19%) concluded the hydrological influence of wetlands to be neutral, insignificant or not to occur. Some 23 of the 28 statements relating to floodplains reported that wetlands reduce or delay floods, less than half (30 of 66) headwaters wetlands statements (bogs, river margins) showed flood reduction and a substantial number (27 of 66) showed headwater wetlands increase flood peaks.

There is strong evidence that wetlands evaporate more water that other land types, such as forests, savannah grassland or arable land. Almost two thirds of statements (48 of 74) concluded that wetlands increase average annual evaporation or reduce average annual river flow. About 10% of statements (7) conclude the opposite; for example some woodlands in Zambia had greater evaporation than the adjacent wetlands. The remaining 25% are neutral. Two thirds of statements (47 of 71) conclude that wetlands reduce the flow of water in downstream rivers during dry periods. This is backed by evidence (22 of 23 studies) that showed evaporation from wetlands to be higher than from non-wetland portions of the catchment during dry periods. In 20% of cases, wetlands increase river flows during the dry season.

Many wetlands exist because they overlie impermeable soils or rocks and there is little interaction with groundwater. The database contains 69 statements referring to groundwater recharge; 32 conclude merely that recharge takes place and 18 conclude there is no recharge. There are similar numbers of studies that report wetlands either to recharge more (6) or less than (9) other land types. Some wetlands, such as floodplains in India and West Africa on sandy soils, recharge groundwater when flooded. Many wetlands have formed at springs and are fed by groundwater.

There are many examples of a diversity of functions for apparently similar wetlands, for example some wetlands promote groundwater recharge, whilst for others the function is absent. The results demonstrate that whilst many wetlands perform important functions beneficial to people, others may operate in a contrary manner. Wetland conservation thus needs to be based on the totality of benefits, including biodiversity and moral considerations.

Making choices between nature and development

The concept of water allocation between ecosystems and direct human use is based on a choice between either development or conservation. The apparent conflict between these two options has been mitigated to a certain extent by recognition of the benefits of ecosystems, which has largely dispelled the idea that water for nature is a loss or a waste. Nevertheless, a trade-off still exists as any allocation of water will result in deferential benefits. This is exemplified by water management issues in the Kihansi river basin Tanzania (Acreman *et al.*, 2006b).

The Kihansi river rises on the Udzungwa plateau approximately 1100m above sea level and falls some 850 m down a vertical escarpment to the Kilombero plain below, through a gorge that contains a series of spectacular water falls. The gorge is very steep and inaccessible, especially during the wet season. Planning for a dam to feed a hydro-power plant to utilise the available head of water began in the 1980s. It was constructed from 1994 to 1999 and commissioned in 2000. The power plant currently has a capacity of 180 MW with the potential to increase this to 300 MW. This level of production requires use of the entire flow of the river (mean 16.3 m^3s^{-1}), which is only returned to the river on the plain.

The initial EIA for the project did not identify any particularly significant ecological impacts. However, in 1998, when the dam was nearing completion, scientists from the University of Dar Es Salaam discovered a small (1 cm) endemic toad in the gorge, whose habitat is created by the spray from the waterfalls, which was thus named the Kihansi Spray Toad. Initial releases from the dam to the falls of 1.9 m^3s^{-1} were made, but these were insufficient to provide adequate habitat for toads. Test releases of 6-8 m^3s^{-1} are planned. Agreement on an acceptable flow release and on maintenance of any mitigation measures has not yet been reached. To mitigate the impact of insufficient environmental flows, water is delivered to the falls area through pipes and forced through nozzles to create adequate spray. Several thousand toads have been sent to the Bronx Zoo in the USA for a captive breeding programme to ensure survival of the species in the event of habitat loss at Kihansi. In 2000, the Lower Kihansi Environmental Project, funded by the World Bank, was created to study the relationship between river flow and spray-toad habitat. LKEMP is now coordinating the ecological studies and is designing a data collection programme.

The Kihansi river basin presents a major dilemma for the Tanzanian government. The Kihansi power station provides a significant proportion of the electricity needs of Tanzania and any reduction in power output would have far-reaching implications for economic development and the profitability of Tanesco. With the high level of poverty within Tanzania, allocating significant water resources for the conservation of the minute toad, in an inaccessible gorge, is politically very sensitive. Whilst the global conservation movement has demonstrated a high existence value for rare species, it is not evident how Tanzania can appropriate this value to offset internal economic losses. However, the Government of Tanzania has signed both the International Convention on Wetlands and the Convention on Biodiversity. In addition, it has developed a new Water Policy (MWLD, 2000) which gives highest priority to water to protect natural ecosystems after basic human needs are met and thus recognises the importance of conserving ecosystems, whose value cannot be measured merely in financial terms.

Conclusions

The past 20 years has witnessed a radical change in thinking about our planet, with widespread recognition of the importance of natural ecosystems and the need to provide them with sufficient water. However, conserving ecosystem functions and services requires a number of inter-related elements, including political will, supporting legislation, well-functioning institutions and sound scientific understanding. Whilst allocation of water to ecosystems may be justified on many grounds including indirect water resource benefits, moral and ethical imperatives, naturally functioning ecosystems cannot provide all requirements of modern human society. Indeed, the allocation of water to sustain natural ecosystems to conserve indirect benefits is a long term decision that may compromise shorter term direct benefits for mankind. The decision as to which benefits to maintain cannot be made by science; it is a question of social choice (Maltby *et al.*, 1999).

References

Acreman, M.C. 1998 Principles of water management for people and the environment. In: de Shirbinin, A. & Dompka, V. *Water and Population Dynamics.* American Association for the Advancement of Science. 321 pp.

Acreman, M.C. 2001 Ethical aspects of water and ecosystems. *Water Policy Journal,* 3, 3, 257-265.

Acreman, M.C. and Dunbar, M.J. 2004 Methods for defining environmental river flow requirements – a review. *Hydrology and Earth System Sciences*. 8, 5, 861-876.

Acreman, M.C. 2005 Linking science and decision-making: features and experience from environmental river flow setting. *Environmental Modelling and Software 20, 99-109*

Acreman, M.C., Dunbar, M.J., Hannaford, J., Black, A., Bragg, O., Rowan, J., King, J. 2006a *Development of environmental standards (Water Resources). Stage 3: Environmental Standards for the Water Framework Directive*. Report to the Scotland and Northern Ireland Forum for Environment Research. Centre for Ecology and Hydrology and University of Dundee. Hydrology and University of Dundee.

Acreman, M.C., King, J., Hirji, R., Sarunday, W., Mutayoba, W. 2006b Capacity building to undertake environmental flow assessments in Tanzania. *Proceedings of the International Conference on River Basin Management, Morogorro, Tanzania, March 2005*. Sokoine University, Morogorro.

Adamus, P.R. and Stockwell L.T., 1983. *A method for wetland functional assessment: Volume I, Critical review and evaluation concepts*. Federal Highway Agency FHWA-IP-82-23, U.S. Dept. of Transporation, Washington, USA. 176pp.

Bullock A, Acreman, M.C. 2003 The role of wetlands in the hydrological cycle. *Hydrology and Earth System Sciences*. 7,3, 75-86.

Commission of the European Communities 1995. *Wise use and conservation of wetlands*. Communication from the Commission to the Council and the European Parliament, Commission of the European Communities COM(95) 189 (final), 54p.

Costanza, R. et al. (1997) The value of the world's ecosystem services and natural capital. *Nature*, 387, 253-260.

Davis, P. and Acreman, M. 2003 *Review of the Interim report of the SRP, the Murray Flow Assessment Tool and the SRP-REG scientific process*. Report to the Murray Darling Basin Commission. MDBC, Canberra, 12pp.

Davis, J. and Claridge, G. 1993 *Wetland benefits. The potential for wetlands to support and maintain development*. Asian Wetland Bureau Publ 87, International Waterfowl and Wetlands Research Bureau Special Publ. 27, Wetlands for the Americas Publ. 11. Asian Wetland

Bureau Kuala Lumpur. 45 pp.
Dugan, P. J., 1990. *Wetland conservation - a review of current issues and required action*. IUCN - The World Conservation Union, Gland, Switzerland, 96p.
European Commission 2000. *Directive 2000/60/EC of 20 December 2000 establishing a framework for community action in the field of water policy*. European Parliament and Council, Luxembourg.
Hollis, G.E., Adams, W.M. & Aminu-Kano, M. (1993) *The Hadejia-Nguru Wetlands: Environment, economy and sustainable development of a Sahelian floodplain wetland*. IUCN, Gland, Switzerland.
Kansiime, F. and Nalubega, M. (1999) Waste Water Treatment by A Natural Wetland:The Nakivubo Swamp, Uganda, Processes and Implications. PhD Thesis, UNESCO-IHE Institute for Water Education, Delft, The Netherlands
OECD, 1996. *Guidelines for aid agencies for improved conservation and sustainable use of tropical and sub-tropical wetland*. Organisation for Economic Cooperation and Development Development Assistance Committee: Guidelines on Aid and Environment No.9, 69pp.
IUCN/UNEP/WWF 1991 *Caring for the Earth - A Strategy for Sustainable Living*. Gland, Switzerland.
Maltby, E., Holdgate, M., Acreman, M.C. & Weir, A. (Eds) 1999. *Ecosystem management; questions for science and society*. Sibthorp Trust.
McNeely, J.A., Miller, K.R., Reid, W.V., Mittermeier, R.A. and Werner, T.B. (1990) *Conserving the world's biodiversity*. IUCN, Gland, Switzerland.
Ministry of Water and Livestock Development 2002 *National Water Policy*. Ministry of Water and Livestock Development, Dar Es Salaam, Tanzania.
Rowlston, W.S. and Palmer, C.G., 2002. Processes in the development of resource protection provisions on South African Water Law. *Proceedings of the International Conference on Environmental Flows for River Systems*, Cape Town March 2002.
Sather, J.M. and Smith, R.D. 1984 An overview of major wetland functions and values. Report to the US Fish and Wildlife Services FWS/OBS-84/18. Washington D.C., 68 pp.