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WATER, WILDLIFE AND PEOPLE

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WATER, WILDLIFE AND PEOPLE

Nature is not competing with us for water but is the primary resource that makes life possible, argues **MARK EVERARD**

Humans depend upon ecosystems. A briefer justification of the need for further development and implementation of the environmental sciences is hard to find. Yet the power and simplicity of this reality does not automatically make it easy to fully comprehend or integrate into a society weaned on resource exploitation rather than interdependence.

From science to reality

Some scientific realities are more readily grasped or acted upon than others. Take gravity, for example. We learn not to fall from trees at an early age. The scientific reality of the inverse square law also needs no great elaboration. It is translated by natural selection into the instinct to 'run away' from perceived danger, and by self-interest into the NIMBY ('not in my back yard') syndrome, whilst military and civil strategists enact it through evacuation, quarantine zones and zonal planning. Whatever our response, the inverse square law is a scientific reality that is as generally and viscerally understood as it is readily deployed to address immediate threats.

But what about the scientific reality of human dependence – for health, wealth creation, quality of life and future security – upon the Earth's diverse ecosystems? We know it to be true, but to what extent do our everyday actions, lifestyles and economic drivers reflect such deeply embedded knowledge?

The services of nature

It was in connection with my work on East African wetlands in the late 1980s that I encountered and used the environmental science ancestral to what we know today as 'ecosystem services'. Evolving thinking about ecosystem services over the past 20 years, particularly its most recent re-conceptualisation in the UN's Millennium Ecosystem Assessment, has been extraordinarily helpful in articulating exactly how ecosystems support so many dimensions of human wellbeing.

The capacity of ecosystems to purify air and water, absorb floodwater, form and regenerate soil, produce food, fibre and decorative materials, and provide spiritual, recreational and characteristic landscapes are just some of the beneficial 'ecosystem services' that make the diverse lifestyles of people across the world possible, profitable and fulfilling. For far too long, we have treated this natural bequest as 'for free', assuming it to be inexhaustible and invulnerable. As a consequence of our largely unwitting carelessness, we live today with degraded and declining ecosystems from marine fisheries to eroding and contaminated land, water scarcity and pollution, collapsing bird and insect populations, and tainted air.

Degradation of ecosystems can not be without consequences in our

"For far too long, we have treated this natural bequest as 'for free', assuming it to be inexhaustible and invulnerable…"

interdependent world. Historic damage to ecosystems results not only in degradation of their extent and quality but also their resilience and capacity to deliver human benefits. Modern industrial lifestyles and booming populations are debilitating nature's capacity to support our collective wellbeing, food and energy security, business interests and continued social advancement. These factors in turn raise issues of equity, as marginalised communities often enjoy the poorest environments and an unequal share of access to natural resources and the profits and power generated from their liquidation.

Waterworld

Water is a particularly significant resource in this regard. Contemporaneous with booms in population and thirsty industrial and agricultural practices has been a transformation of landscapes that has compromised the capacity of catchments to deliver the essential ecosystem services of interception, storage and recirculation, purification and buffering of flows of fresh water. Climate change is likely to intensify this ever-deepening conflict. Hence, water scarcity is likely to become the prime limiting factor to human development worldwide and, unless our habits change dramatically, to fuel international resource-based conflicts beyond those already witnessed in the Middle East.

The importance of this for the future prospects of biodiversity and humanity cannot be overestimated. Through this journal, we will explore various dimensions of the interdependence of people, water and the ecosystems that supply multiple benefits to society.

Societal attitudes to nature

It is important to stress that our interaction with nature has inevitable ecological, social and economic consequences – positive or negative – each comprising an interdependent facet of the same greater system.

> 'This industrial mindset often assumes that we can engineer our way out of problems by using the same technocratic paradigm that caused them in the first place'

The technocentric worldview that has shaped the developed world for more than two centuries has generally regarded the natural world purely as a resource to be exploited for profit, blind to or in denial of longer-term consequences such as those now confronting our future wellbeing. We have historically ascribed to nature no inherent value, instead treating it as property to be annexed, exploited or traded. The goods we derive from nature's services comprise markets but, ironically and destructively, we exclude nature itself.

This industrial mindset often assumes that we can engineer our way out of problems by using the same technocratic paradigm that caused them in the first place. For example, some vested interests presume a need for more dams or deeper boreholes to harvest more water from the landscape, piped ever more distantly to provide for the predicted needs of conurbations, industries and large-scale farming. This model continues to serve those already favoured by large-scale technology and investment, and to overlook the needs of rural and marginalised human communities that have also been historic victims of the centralisation of resources to an economic elite. Significantly, nature is also seen as a competitor for dwindling water supplies.

We are now waking up to the need for transition to a future increasingly shaped by sustainability principles, a future in which we seek to identify, protect and, ideally, restore the natural capital that we now know to be the sole and irreplaceable source of the ecosystem services that underwrite our future prospects. And, in this progressive, eco-centric model, nature is realised to be not a competitor for water but, in fact, the primary resource that makes life possible, profitable and fulfilling. The reality is that our future rests upon the integrity, productivity, resilience and continued functioning of nature.

Telling tales

Hence the theme of this edition of *Environmental Scientist*. We could perhaps have subtitled it 'ecosystem services'. However, had we done so, we might have been complicit in advancing understanding only amongst a narrow technical elite already *au fait* with the concept. This would not best serve the broader promotion of sustainable development nor, therefore, the purpose and duty of our profession.

Better then to visit episodes in the story of the interdependence of people, wildlife and water, and to relate stirring tales of real progress that make a real difference to real people. Better to produce a sequence of narratives that, while grounded in the environmental sciences, have meaning for and may best induce change in the wider community.

Then, maybe, we'll have taken a further step towards public appreciation and proportionate response – much as we appreciate the inverse square law by 'running away' – to the scientific reality of our collective dependence upon the Earth's supportive ecosystems.

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REBALANCING THE INTERESTS OF WILDLIFE AND PEOPLE

We have a higher awareness than ever before of our wildlife's decline, but there is still a lack of co-ordinated effort in halting or reversing it, says **PAUL RAVEN**

In Britain, there is a great affinity for wildlife. Over half the population said they took an interest in wildlife in a BBC poll of 2006. In a 2007 poll commissioned by the Environment Agency, 76% of people in the East of England claimed to have altered their behaviour to reduce their carbon footprint.[1] More than four million of us belong to one or more voluntary wildlife organisations, several of which now have advanced commercial and communication infrastructures to promote their message.

Britain has an advanced phalanx of legislation on issues ranging from conservation to targets for revitalising depleted species. Nevertheless, despite the hundreds of millions of pounds spent each year, the RSPB has estimated that a further £300m is needed to fully implement the UK Biodiversity Action Plan (BAP), a scheme to protect the most threatened organisms and habitats.

Despite all the progress made in wildlife conservation, the general principles of ecosystem services have still not been widely incorporated into the processes of commercial enterprises. As these have a greater cumulative influence on public behaviour and spending than central or local government, this is significant. We now have a higher awareness than ever before of our wildlife's decline, but there is still a lack of co-ordinated effort in halting or reversing it.

Air and water quality have improved over the last 20 years, thanks to investments made to comply with stricter environmental regulations. Several species have made an impressive recovery as a result: examples include birds of prey such as the peregrine falcon and sparrowhawk, following a ban on certain pesticides; mute swan populations after a ban on lead fishing weights; the return of otters to former habitats following reductions in pollution loads from persistent organochlorine compounds; and fish fauna in rivers and estuaries that were badly polluted (including the Thames, Mersey and Tyne).

There are also good examples of where changes in land management have benefited biodiversity: corncrakes returning to farmland in eastern Scotland are just one example.

1. Conducted by Ipsos Mori and published on 17 May 2007.

These are classic examples of publicised threats to well-known species that, over time, provoked results. The lesson is an encouraging one: raised levels of awareness often lead to action, and nature's resilience shines through.

Encouraging examples of wildlife recovery (in relation to government commitments to 2010 targets) need to be tempered by similar advertisement of the continuing degradation and habitat fragmentation in the wider countryside, towns and around our coasts. We need to appreciate wildlife as a proxy indicator of environmental and economic health, and to promote good practice across planning, commercial and industrial sectors. The science needs to be popularised, without too much 'dumbing down'. It must be understood that the 'state of wildlife' index is directly related to sustainable long-term use of natural resources. We need to illuminate the connections between, on the one hand, the impact (and cost) of such degradation and the unsustainable exploitation of resources and, on the other, the benefits of better husbandry and quality of life.

The Water Framework Directive, with its underlying principle of sustainable use of resources, provides a great opportunity for getting that message across, at national and local level. For the first time, ecological objectives will be used to drive action to improve environmental quality and sustainable use of river catchments and coastal waters. Wildlife (and not just conservation) will be the focus. As watercourses and estuaries are conduits which link activities across the ecosystems humans and wildlife share, the links between ecology, pressures (e.g. pollution, drainage, urbanisation, habitat degradation) and the action needed to redress such unsustainable activities will be exposed. In late 2008, river basin liaison panels will measure ecological parameters as a metric of environmental health, the scale and location of pressures acting on the environment, the practicalities, costs and timescales for preventing deterioration and achieving improvements, and assumptions about the problems identified and the best ways of dealing with them.

> 'The general principles of ecosystem services have still not been widely incorporated into the processes of commercial enterprises…'

There are several examples of practical action to restore ecosystem functioning. Numerous river restoration and rehabilitation works have been carried out (e.g. demonstration sites on the River Skerne in Darlington, the River Cole in Oxfordshire or the Quaggy River in South-East

London) but the benefits have been very localised. Larger-scale re-naturalisation along river corridors and ambitious plans to re-wild catchments (led for example by the National Trust, private estates or river trusts) have also been attempted or are planned. But these are largely in remote areas, where wider public benefits may be marginal.

> ‘We have a unique opportunity to place ecosystem functioning in the spotlight, highlighting the links between healthy wildlife and socio-economic benefits in terms that the public can understand’

Small-scale but effective upland peatland projects (e.g. SCaMP or the Exmoor Mires project), where old drainage channels have been blocked to re-water moorland, restore hydrological functioning, reduce peat colour and attenuate flood risk provide positive examples of simultaneous public and wildlife benefit. They also have great potential for wider application. Several EU-funded LIFE projects[2] have also demonstrated the potential of well-targeted work in catchments and along the coasts in restoring or mimicking natural processes to reduce soil or coastal erosion at hotspots.

There is no lack of studies, models and small-scale practical action that provide evidence of benefits. The problem is that historical degradation of habitats and soils has been so widespread that trying to reverse the trends and re-establish natural functioning is a massive task that requires concerted action. There must be incentives if we are to ensure that landowners and managers take part.

Reform of the EU Common Agricultural Policy, including the UK's introduction of cross compliance and its Entry Level and Higher Level agri-environment schemes, is unlikely to make a huge difference to the long-term decline of wildlife. The capacity of ecosystems to recover will be eroded further unless the trend is reversed. Luckily, remnant populations of peregrine falcons and otters were available to enable natural re-colonisation. There are other cases (e.g. biological recovery from acidified streams in upland Wales) where destruction of the remnant refuge communities and populations has prevented recovery.[3] There are several factors which provide optimism for understanding, support and implementation of the ecosystem approach:

- public sympathy for wildlife;
- a wealth of investigations and research showing the theory and practice of ecosystem functioning; and
- high-profile examples of successful recovery following specific legislation (e.g. banning pesticides).

Still lacking are:

- effective promotion of public and socio-economic benefits of natural ecosystem functioning;
- a strategic spatial planning strategy that has sustainable development and ecosystem services as key underlying principles;
- incentives at a level concomitant with the provision of public service ‘goods’ (e.g. flood risk attenuation; water purification); and
- recognition that long-term costs of imbalance (e.g. excessive soil erosion) far outweigh that of restoring natural processes.

It is widely recognised that reducing ‘pressure points’ on natural processes is a key principle in adapting to climate change. We have the basic evidence and knowledge about how catchment and coastal processes operate and how they respond to artificial pressures. We also know that wildlife recovery is possible where favourable conditions are restored and sufficient remnant populations are able to recolonise.

We also know that naturally-functioning ecosystems cannot be restored everywhere, at least not in the foreseeable future. But, equally, we know that allowing the remaining examples to degrade further simply doesn't make economic sense. ‘Re-plumbing’ catchments would be a good start, and we now have the strategic planning tool that provides the ‘opportunity map’ for wetland restoration that planners have long asked for – the Wetland Vision for England.[4]

Perhaps the combination of the need to adapt to climate change, the opportunities presented by the ecological focus of the Water Framework Directive, strategic planning tools such as the Wetland Vision and greater public awareness of the goods and services provided by natural process will provide the compelling case for change. This is change from which commerce, industry, landowners and the public will all benefit – based on long-term economic incentives and opportunity rather than regulation. In short, we have a unique opportunity to place ecosystem functioning in the spotlight, highlighting the links between healthy wildlife and socio-economic benefits in terms that the public can understand and to which all sectors need to respond.

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2. *www.ec.europa.eu/environment/life/home.htm*
3. N.S. Weatherley (1988), ‘Liming to mitigate acidification in freshwater ecosystems: A review of the biological consequences’, Journal Water, Air and Soil Pollution, 39, pp.421-437)
4. *www.wetlandvision.org.uk*

WHY WETLANDS MATTER TO PEOPLE

Wetlands are crucial in providing a range of benefits for society and for maintaining human wellbeing. So why do we risk destoying them, asks ROB MCINNES

Around 6000 BC, Neolithic farmers began to migrate into the plain forming a 'fertile crescent' bordering the Tigris and Euphrates rivers, known in ancient days as Mesopotamia (derived from the Greek meaning literally 'between the rivers'). The lower reaches of this plain encompassed two geographical areas, Akkad in the north and Sumer, the delta of this river system, in the south.

Dissected by river channels abounding with fish and revitalised by alluvial silt laid down routinely by uncontrolled floods, Sumer possessed phenomenal potential for agriculture, if the environment could be tamed. In the words of V. Gordon Childe, one of the great archaeological synthesizers of the 20th century, 'arable land had literally to be created out of a chaos of swamps and sand banks by a "separation" of land from water; the swamps… drained; the floods controlled; and life-giving waters led to the rainless desert by artificial canals.'

Over the course of several successive cultural phases that followed the arrival of the first Neolithic farmers, a range of environmental challenges were solved by co-operative effort. Between 3500 BC and 3100 BC, the foundations were laid in this region for a type of social order and economy markedly different from anything previously known. This was a far more complex culture, based on large urban centres rather than simple rural villages. Here man first attempted to write, develop formal education programmes and evolve legislative systems. The large-scale control of the environment and the resultant urbanisation heralded important new discoveries in sciences such as medicine, chemistry, astronomy and mathematics, and a bloom of creativity in arts, literature and craftwork. These advances established the foundations on which the civilised world, some five millennia later, depends.

Four thousand years after the Sumerians had begun to master the Tigris and the Euphrates, the Khmer kingdom of Angkor rose in the ninth century AD. It thrived for 600 years before its leaders left to resettle near the modern Cambodian capital of Phnom Penh. The civilization is renowned to this day for the prodigious temple of Angkor Wat, often called the world's largest single religious monument. However, ever since 16th century Portuguese traders became the first westerners to spy its choked ornate towers reaching out from the dense forest canopy, controversy has smouldered among archaeologists as to why such an impressive site was abandoned.

Even taking a conservative viewpoint, at more than 3,000 square kilometres, Angkor, at its peak, is considered to be the world's most extensive pre-industrial low density urban complex. The vast area is traversed by rectilinear embankments which would have enclosed artificial ponds and probable rice paddies, while earthen mounds elevated houses to avoid seasonal floods. A complex of waterworks diverted water from the Puok, Roluos, and Siem Reap rivers to reservoirs that could be drained to irrigate crops or filled to attenuate extreme flood events.

Until recently, warfare and religious conflicts were the prime suspects in the degradation of the site. However, there is growing consensus that it may be one of the earliest catastrophic examples of unsustainable development and inappropriate wetland management. A thesis describing overexploitation, overpopulation and deforestation was first proposed in the late 1970s by Bernard-Phillipe Groslier[1] of the École Française d'Extrême-Orient (EFEO). Recent work led by archaeologist Damian Evans[2] of the University of Sydney has added weight to this theory. There is evidence to suggest that the extensive waterways which threaded through the low-density development, channelling the flow of the three rivers through agricultural fields, homes, and local temples, may have been instrumental in contributing to the civilisation's demise. As population expanded, forests were cleared for agriculture, potentially exacerbating erosion and flooding. Surveys have uncovered a breached spillway filled with blocks from walls that had tumbled down or were possibly pushed into the channel and buried in sand. Similarly, thick layers of sediment deposited by turbid floodwaters have filled in canals and watercourses. There is also evidence of *ad hoc* adaptations, breaches, modifications, and failures within this system, suggesting that it became increasingly complex and unmanageable over several centuries of development.

1. Groslier, B-P. 1979. Bull. Éc. Fr. Extrême-Orient, 66. 161–202pp.
2. Evans, D., Pottier, C., Fletcher, R., Hensley, S., Tapley, I., Milne, A. and Barbetti, W. 2007. A comprehensive archaeological map of the world's largest preindustrial settlement complex at Angkor, Cambodia. Proc. Nat. Acad. Sci., 104 (36). 14277–14282pp.

What has history taught us?

It is widely accepted that more than 50% of specific types of wetlands were destroyed in parts of North America, Europe, Australia, and New Zealand during the twentieth century, and many others degraded worldwide. The Millennium Ecosystem Assessment[3] reported rather grimly that the degradation and loss of wetlands, and the deterioration of freshwater and coastal wetland species, are more rapid than that of other ecosystems. It is apparent that we continue to mismanage wetlands and fail to learn from the lessons delivered over five thousand years of human development.

Today, there are many direct and indirect drivers of degradation and loss of wetlands. Population growth and increasing economic development precipitate a range of impacts. Infrastructure development, land conversion, water withdrawal, eutrophication and pollution, over-harvesting, the introduction of invasive alien species, all contribute to wetland loss and degradation. Factor in the prowling spectre of global climate change, which is expected to exacerbate these impacts, and the future for wetlands looks bleak.

Despite being the life-blood of human civilisation, wetlands continue to be considered and managed in an unsustainable manner. The implosion at Angkor Wat and the salutary messages humankind should have taken from such events continue to fall on deaf ears.

We degrade and lose wetlands. So what?

From the dawn of civilisation, the fortunes of wetlands and humans have been inextricably linked in a turbulent, symbiotic marriage. Over recent decades, researchers have demonstrated that wetlands are crucial in providing a range of benefits for society and for maintaining human wellbeing. The Ramsar Convention on Wetlands[4] has promoted the wise use of wetlands as a means of maintaining their ecological character and the ecosystem processes and structure which underpin the delivery of these benefits (now classified as 'ecosystem services').

Ecosystem services can be considered as the 'benefits people obtain from nature'. As we degrade wetlands, we compromise our own quality of life through an erosion of these benefits. This is especially true for poorer people in lower-income countries, where technological solutions are not as readily available to replicate the natural benefits derived from wetlands.

Wetlands do matter

Both inland and coastal wetlands significantly influence the hydrological cycle, and hence water supply and the many uses we make of it including irrigation, energy, and

3. Millennium Ecosystem Assessment. 2005. Ecosystems and Human Health: Water and Wetlands Synthesis. World Resources Institute. Washington DC, USA. 68pp.
4. *www.ramsar.org/*

transport[5]. Changes in hydrology, either natural or anthropogenic in origin, in turn affect wetlands.

Wetlands deliver a wide array of hydrological services, for instance, swamps, lakes and marshes assist with flood mitigation, promote groundwater recharge and regulate river flows. The nature and value of these services differ across wetland types.

Flooding is a natural phenomenon important for maintaining the ecological functioning of wetlands (for example by serving as a means for the natural transport of dissolved or suspended materials and nutrients into wetlands). It was the natural flood pulse along the Tigris and Euphrates which delivered the necessary fertile conditions for civilisation to flourish in Mesopotamia.

Many wetlands diminish the destruction wrought by flooding, while the loss of wetlands increases the risk of floods. Wetlands, such as floodplains, lakes and reservoirs, are the main providers of flood attenuation potential in inland water systems. Globally, nearly two billion people live in areas of high flood risk, a risk that is exacerbated as wetlands are lost or degraded.

> ‘Despite being the life-blood of human civilisation, wetlands continue to be considered and managed in an unsustainable manner’

The principal supply of renewable fresh water for human use comes from an array of inland wetlands, including lakes, rivers, swamps and shallow groundwater aquifers. Groundwater, often recharged through wetlands, plays an important role in water supply, with an estimated 1.5-3 billion people dependent on it globally as a source of drinking water. Rivers have been substantially modified around the world to increase the water available for human consumption. Recent estimates place the volume of water trapped behind (documented) dams at 6,000 to 7,000 cubic kilometres.

Physical and economic water scarcity, and limited or reduced access to water, are major challenges facing human society and are also key factors limiting economic development in many countries. This is a global problem, directly affecting one to two billion people worldwide, hindering growth in food production and harming human health and economic development.

Continued degradation of water quality increases the prevalence of waterborne diseases, especially for vulnerable people in developing countries where technological fixes and alternatives are not readily available. Inadequate water, sanitation, and hygiene account for 1.7 million deaths and shorten lives by a total of 54 million healthy years annually. Although largely eliminated in wealthier nations such as the UK, water-related diseases (malarial and diarrhoeal diseases, for instance) are among the most common causes of illness and death in developing countries. The poor are the most at risk.

One of the most important benefits provided by wetlands is the provision of food. Some people, particularly those living near wetlands, are highly dependent on this ecosystem service.

Inland fisheries are of particular importance in developing countries, and they are sometimes the primary source of animal protein to which rural communities have access. For example, the descendants of the Khmer kingdom around Angkor in Cambodia obtain about 60-80% of their total animal protein from the fishery in Tonle Sap and associated floodplains.

Wetland-related fisheries also make important contributions to local and national economies. Capture fisheries in coastal waters alone contribute US$34 billion to gross world product annually.

Wetlands provide significant cultural, aesthetic, educational and spiritual benefits, as well as a vast array of opportunities for recreation and tourism. In developing countries recreational and ‘green’ tourism opportunities associated with wetlands are receiving increasing attention as a low-impact, non-consumptive development option, and an opportunity to attract financial investment or to generate significant income. Similarly, tourism is seen as an important incentive for conservation and a key source of funding for protected areas.

Recreational fishing can generate considerable income: 35 to 45 million people take part in recreational fishing (inland and saltwater) in the United States, spending a total of US$24 to 37 billion each year on their hobby[6].

A ‘willingness to pay’ study undertaken in the Djoudj National Bird Park, located in the Senegal River Delta, Senegal, indicated that the visitor admission price could be increased from approximately £2.10 per person to about £7.00 (based on an open-ended question approach) or in excess of £18.00 (based on close-ended question approach). This demonstrated that the total annual revenue for 2002 could have been in the region of £83,000 to £150,000, compared to an actual revenue of slightly more than £30,000[7].

5. Bullock, A. and Acreman, M.C. 2003. The role of wetlands in the hydrological cycle. Hyd. Earth Sys. Sci. 7(3). 358-389pp.
6. Feather, P., Hellerstein, D.and Hansen, L. 1999. Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP. Resource Economics Division, Economic Research Service, US Department of Agriculture. Agricultural Economic Report 778. Washington DC, USA.

Of increasing concern is the role of wetlands in mitigating or contributing to climate change. A recent expert meeting co-convened by the CBD (Convention on Biological Diversity) and Ramsar concluded that the release of carbon resulting from wetland degradation will offset the gains made by the world community to reduce greenhouse gas emissions. Wetlands are critically important for both mitigation (reducing the rate of CO_2 increases in the atmosphere) and adaptation (dealing with the severe impacts of climate change).

One of the most important roles of wetlands may be in the regulation of global climate change through sequestering and releasing a substantial proportion of fixed carbon in the biosphere. For example, peatlands cover only an estimated 3 to 4% of the world's land area yet are estimated to hold 540 gigatons of carbon. The carbon load is about 1.5% of total estimated global carbon storage and about 25 to 30% of that contained in terrestrial vegetation and soils.

Sea level rise and increases in storm surges associated with climate change will result in the erosion of shores and habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, and increased coastal flooding and, in turn, could increase the vulnerability of some coastal populations. Wetlands, such as mangroves and floodplains, can play a critical role in the physical buffering of such climate change impacts.

> As we degrade wetlands, we compromise our own quality of life through an erosion of these benefits

The Millennium Ecosystem Assessment recognised that biodiversity forms the foundation for the vast array of wetland ecosystem services that critically contribute to human wellbeing. Changes in biotic interactions among species, predation, parasitism, competition and facilitation can lead to disproportionately large, irreversible, and often negative alterations of ecosystem processes. Similarly, many changes in ecosystem services are brought about by the removal or introduction of organisms that disrupt biotic interactions or ecosystem processes. Because the network of interactions among species and the network of linkages among ecosystem processes are complex, the impacts of both the removal of existing species and the introduction of new ones are difficult to anticipate.

> …until the real value of the benefits they bestow on society is recognised and incorporated into legislation, wetlands will continue to be seen as free resource

One of the highest profile examples of enhancing and conserving biodiversity in order to improve the provision of ecosystem services comes from the USA. Before it became overwhelmed by agricultural and sewage runoff, the watershed of the Catskill Mountains provided New York City with water ranked among the best in the USA[8]. When the water fell below acceptable quality standards, the City investigated the cost of installing an artificial filtration plant. The estimated price tag for this new facility was between six and eight billion dollars, a high price to pay for a supply that was once considered free. New York City decided instead to invest a fraction of that cost (US$660 million) in restoring the natural capital it had in the Catskill's watershed. In 1997, the City raised an Environmental Bond Issue and is currently using the funds to purchase land and halt development in the watershed, to compensate property owners for development restrictions on their land, and to subsidise the improvement of septic systems.

Healthy wetlands, healthy people

Healthy wetlands are critical to human well-being. However, until the real value of the benefits they bestow on society is recognised and incorporated into governmental policies and legislation, wetlands will continue to be seen as free resource subject to unfettered abuse.

Increasingly, it is being accepted that social sustainability is a prerequisite for environmental sustainability. If the societal benefits derived from wetlands remain unacknowledged, social sustainability will be compromised. The resultant unsustainable management of wetlands could place society in the same position as the people of Angkor some 500 years ago; the difference is that we have seen the warning signs and we have a chance to act on them and recognise the fact that wetlands are critical to human wellbeing.

7. Oumou, K.L., Bishop, J.T., Moran, D. and Dansokho, M. 2006. Estimating the value of ecotourism in the Djoudj National Bird Park in Senegal. IUCN, Gland, Switzerland. 34pp.
8. Ashendorff, A., Principe, M.A. and Mantus, J. 1997. Watershed protection for New York City's supply. Journal of the American Water Works Association. 89 (3). 75-86.

TAKING AN ECOSYSTEMS APPROACH

The ecosystems approach offers a basis for more equitable and sustainable decisions about sharing crucial resources. BERNICE C. CULLIS describes the implementation of South Africa's National Water Act

Technologies exploiting natural resources for human advantage across the world have yielded many benefits. However, we are now realising that many of the ways we exploit natural resources result in adverse consequences for the health and functioning of ecosystems and, by implication, all people who depend upon them.

At the global level, the UN's Millennium Ecosystem Assessment (MA) evaluated the impacts of human activities on global ecosystems, determining the implications of ecosystem capacity to support human wellbeing into the future. The MA concluded that global ecosystems are in parlous decline due to human exploitation, compromising both their integrity and also their potential to support human livelihoods and wellbeing into the future. These conclusions can be found in the various reports from the MA published between 2004 and 2005. However, we are focusing here on the MA's redefinition of the concept of 'ecosystem services' and the strong recommendation for future development to take an 'ecosystems approach' (i.e. founded upon ecosystem services). We set this in the context of water management in South Africa.

A new definition of ecosystem services

The concept of ecosystem services is not new. It has been under development for over twenty years, formerly encompassing 'goods' (tangible and tradable materials such as timber, grazing, clean water, etc) and 'services' (less tangible processes such as air and water purification, soil fertilisation, pest control, cultural and spiritual values, etc) However, the MA has given the concept renewed impetus by reviewing and integrating strands of research relating to how the functions performed by ecosystems provide benefits to humanity, harmonising concepts developed for discrete ecosystems into an holistic suite applicable to all ecosystems. This MA list of ecosystem services is summarised in Box 1.

Box 1: the MA's re-definition of ecosystem services

- **Provisioning services** (tangible 'goods' of value to society)
  - Fresh water
  - Food (e.g. crops, fruit, fish, etc)
  - Fibre and fuel (e.g. timber, wool, etc)
  - Genetic resources (used for crop/stock breeding and biotechnology)
  - Biochemicals, natural medicines, pharmaceuticals
  - Ornamental resources (e.g. shells, flowers, etc)
- **Regulatory services**
  - Air quality regulation
  - Climate regulation (local temperature/precipitation, GHG sequestration, etc)
  - Water regulation (timing and scale of run-off, flooding, etc)
  - Natural hazard regulation (i.e. storm protection)
  - Pest regulation
  - Disease regulation
  - Erosion regulation
  - Water purification and waste treatment
  - Pollination
- **Cultural services**
  - Cultural heritage
  - Recreation and tourism
  - Aesthetic value
  - Spiritual and religious value
  - Inspiration of art, folklore, architecture, etc
  - Social relations (e.g. fishing, grazing or cropping communities)
- **Supporting services** (processes maintaining ecosystem integrity and functioning)
  - Soil formation
  - Primary production
  - Nutrient cycling
  - Water recycling
  - Photosynthesis (production of atmospheric oxygen)
  - Provision of habitat

Though any such harmonised list will never be completely matched to the nuances of every ecosystem type and cultural utilisation – for example the additional ecosystem service of 'fire control' has been used in South Africa to augment the basic MA set of ecosystem services reflecting particular attributes of impacted and un-impacted South African catchment ecosystems – the redefined list of ecosystem services provided by the MA is helpful in covering the major contributions of ecosystems to human utility and value.

This synthesis of ecosystem services helps us recognise the diverse benefits provided to society by ecosystems, many of which have historically been ignored or taken for granted with inevitable negative consequences. The MA's re-definition of ecosystem services also helps identify how some forms of ecosystem exploitation can create advantages for some sectors of society whilst coincidentally, and often unintentionally, degrading the benefits enjoyed by other people. It thereby provides a valuable framework for comparing different development options in order to discover which secure the greatest benefits for the wide constituencies of people making use of shared ecosystem resources, such as catchments.

The MA strongly advocated that decision-makers at all scales and across the world take an ecosystems approach, supporting more inclusive and sustainable decisions founded on implications for the ecosystem services upon which society depends.

‘This synthesis of ecosystem services helps us recognise the diverse benefits provided to society by ecosystems, many of which have historically been ignored or taken for granted with inevitable negative consequences’

Aspects of the ecosystems approach are already in place around the world. For example, it is the intent of catchment management strategies to better consider interactions between functions (such as water quality, conservation, and fisheries) across a drainage basin. However, the holistic ecosystems approach offers us a more powerful means by which to determine how to share limited and vulnerable natural resources to achieve the greatest and most enduring benefit for all people, rather than just the narrower and more localised benefits accruing to those promoting specific development proposals. It may also help us highlight critical ecosystem services for which habitat needs to be protected or restored for the greater benefit of all.

It is therefore not surprising that the ecosystems approach is beginning to be embraced more fully by governments around the world. This includes, for example, the framing of policies for ‘open seas’ fishery exploitation within the European Union, the USA and Malawi, and internationally.

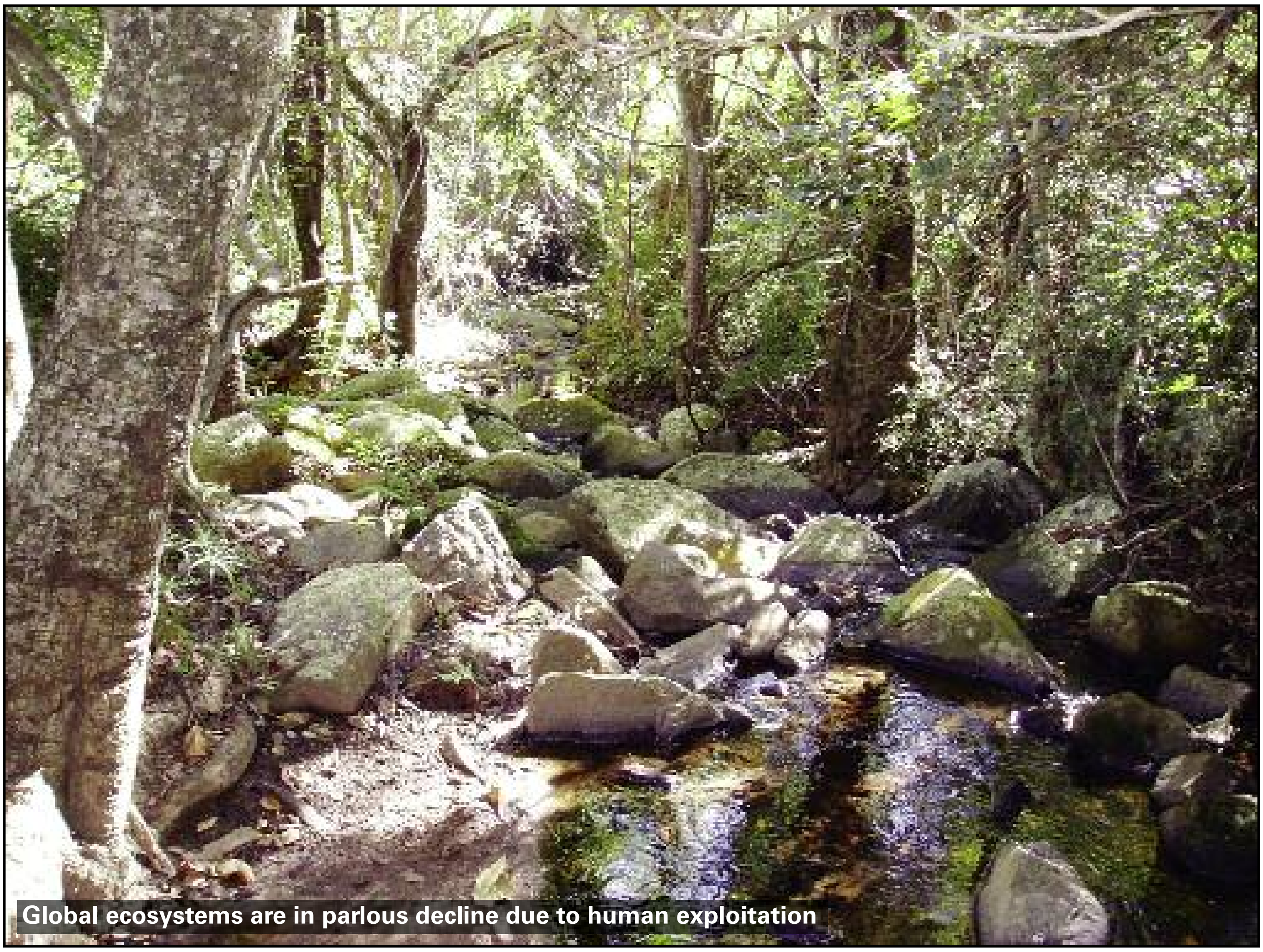
Taking an ecosystems approach to water management in South Africa

During the period of democratic reform in South Africa, it had become evident that an holistic approach to water resource management was required. As one consequence of a patient and thorough dialogic process, the ecosystems approach became embedded as an implicit part of the three central driving principles – equity, sustainability and efficiency – of South Africa's National Water Act 1998. This ground-breaking legislation requires us to work with all stakeholders across catchments to determine how to share finite catchment ecosystem services to achieve the greatest public benefit.

One of the ways in which this is being accomplished is by bringing together all of the diverse bulk and raw water users, classified under eleven legal uses of water under the National Water Act, to enable the more efficient, equitable and sustainable management of water. As officials working under the Institutional Establishment sub-directorate of the Department for Water Affairs and Forestry (DWAF) in the province of KwaZulu-Natal, it is our job to engage with stakeholders on all levels and to develop an integrated dialogue regarding short-, medium- and long-term measures for managing water resources within catchments. Though water allocation is set by permit, the National Water Act seeks to reach this end-point by developing consensus amongst the diverse communities within catchments about how they will share limited water resources. Our process of dialogue and consensus-building allows all interested and affected parties within catchments to voice aspirations and concerns as well as to work together to find solutions. This process is complex, but it is necessary, valuable and eventually more sustainable.

Management of the Mgeni River

Management of the complex and heavily-utilised Mgeni river system illustrates the process in action. The Mgeni catchment is located in the Province of KwaZulu-Natal, within the Mvoti to Mzimkhulu water management area (WMA). (A WMA is a legally-defined ‘super-catchment’ comprising a number of river systems.) The Mgeni provides the essential ‘life force’ of water to the urban corridor of Pietermaritzburg and Durban, as well as a far wider outlying rural area comprising a range of land uses. The total area of the Mgeni catchment is 4,441km^2 with a mean annual runoff (MAR) of 671 million m^3/acre. The main water use activities in upper regions of the catchment are commercial afforestation and crop irrigation (including significant areas of sugar cane), while domestic and industrial uses dominate in the middle and lower catchment. Regulation of bulk/raw water use across the


Global ecosystems are in parlous decline due to human exploitation

catchment involves many players with interdependent needs.

Being such a large river, the Mgeni naturally produces a wide range of ecosystem services benefiting the many people who live within it. From source to sea, it incorporates a large wetland (the Umgeni Vlei) and is also interrupted by four storage dams (Midmar, Albert Falls, Nagel and Inanda) which supply domestic water to the urban nodes. Other valued ecosystem services include fishing, water abstracted for irrigation, assimilation of effluent and industrial pollution, and sand mining. The river also runs through land controlled by tribal authorities where, in addition to the services already noted, it is a focal point for religious ceremonies such as baptisms. The Mgeni system also offers its services on a global scale, notably including serving as the venue for the internationally renowned Duzi Canoe Marathon and the Midmar Mile swimming event.

All this then requires a river of sufficient quality, flow and natural character, which in turn depends upon regulation and management to control the impacts of many competing uses and pressures. Within the framework of the National Water Act and its subsidiary National Resource Strategy, the waters of the Mgeni are regulated and monitored in terms of licensing and registration, water quality, geohydrological monitoring and registration, and water resource management, institutional establishment and maintenance. This approach necessarily seeks to treat the river as a whole integrated system, rather than as a set of discrete and disconnected reaches.

Institutional arrangements for systemic management

How are all these disparate strands brought together? Consequent from the National Water Act, we are establishing a range of new water management institutions with the purpose of managing water resources in an integrated manner – looking at the whole, not the sum of its parts.

As addressed by Weston and Weston elsewhere in this journal, Catchment Management Agencies (CMAs), established on a supra-catchment basis, are one of the principal sets of institutions with responsibility for licensing of water use. These are supported by other organisations at catchment and sometimes sub-catchment scale, significantly including Water User Associations (WUAs) which are statutory bodies comprising appropriate stakeholder representation to determine how best to share water within catchments. Further non-statutory bodies, Catchment Management Forums (CMFs), are established and maintained as a platform for integrated water resource management (IWRM) and for information dissemination.

On the Mgeni River System, a total of four CMFs have been established at strategic points on the system to provide a space and platform for relevant stakeholders to discuss diverse issues and problems pertaining to the management of water within that river reach. The stakeholder base of these forums include: various DWAF components; other government departments whose mandates cover land use, mineral management and other biodiversity components; local and district municipalities; parastatals (environment and water service providers); tribal authorities; non-governmental organisations; commercial and emerging agricultural sectors; forestry; industry; and private, concerned individuals.

These CMFs also allow DWAF to present to the diverse stakeholders the ongoing initiatives conceptualised by the Department to pursue and maintain IWRM. Programmes concerning water conservation, better sanitation and water resource education are addressed to the forum. Input from CMF members is valuable in the roll-out of these initiatives.

> ‘As one consequence of a patient and thorough dialogic process, the ecosystems approach became embedded as an implicit part of the three central driving principles – equity, sustainability and efficiency – of South Africa's National Water Act 1998’

Although the range of bodies entailed in water management is diverse, and the process of engaging all relevant stakeholders in dialogue is painstaking, it is necessary to ensure that decisions are equitable, sustainable and efficient. The sharing of ecosystem services by all people within catchments is an important departure from prior ‘command and control’ management for the advantage of only a small sector of society. The range of ecosystem services provided by catchments form a basis for negotiation and agreement about equitable and durable development strategies. Our new approach is therefore open and transparent, inclusive of all relevant interested and affected parties towards optimal solutions for all people sharing catchments.

> ‘The approach offers us a framework for making more equitable, sustainable and efficient decisions with respect to the sharing of the crucial resources and processes of ecosystems that underwrite continuing human wellbeing’

The value of the ecosystems approach across South Africa

An ecosystems approach can be extremely helpful as South Africa grapples with the tough challenge of implementing its visionary National Water Act. It can help, for example, by:

- identifying critical areas of ecosystem functioning within catchments that warrant particular protection or restoration, for example the extensive upland grasslands on the Drakensberg which are critical for water capture, storage and purification for the benefit of much of South Africa;
- providing a common conceptual framework for communication and for consensual decision-making with stakeholders about the implications of decisions over water use for other ecosystems services and the people who depend upon them;
- framing our thinking about appropriate technologies that better address the needs of all people, rather than depending on traditional engineering geared historically to maximising benefits only for targeted sectors of society.

The ecosystems approach offers us a framework for making more equitable, sustainable and efficient decisions with respect to the sharing – and perhaps even the restoration – of the crucial resources and processes of ecosystems that underwrite continuing human wellbeing and progress.

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VALUING ECOSYSTEM BENEFITS

How can you put a price on a saltmarsh or a flood bank? **WILLIAM WATTS** and **INO KREMEZI** of the Environment Agency discuss the problems of valuing the benefits provided by ecosystems

The UK government's Department for Environment and Rural Affairs (Defra) has recently published two linked, barely noticed documents that together represent a substantial shift in how government views and values the natural world.

The two documents, one a policy action plan and the other a guide to practitioners, introduce the concept of 'ecosystem valuation' to government decision-making[1,2]. Arguably, this is the most significant event since the publication of the 'green leaves guide' in the early nineties by the then Department of the Environment[3]. 'Green leaves' (so-called because of the sylvan fantasy on the cover) legitimised the use of environmental valuation within government, but ultimately did not get government departments to move beyond the rhetoric to the execution stage.

Until now, the process of environmental valuation has often been intractable because of cost and confusion over what was being valued. The development of the UN Millennium Ecosystem Assessment (MA) has helped to unclog this impasse, by deconstructing the idea of habitat valuation. It concentrates on what services ecosystems provide, rather than trying to value them as a whole.

The ecosystem services approach to policy analysis and delivery is perhaps better described as detailing what an ecosystem does for us, the human community. It describes how people are dependent on the natural environment. It explicitly recognises that ecosystems and the biological diversity contained within them contribute to human well-being (or 'welfare' in economic terminology). This extends beyond the provision of goods such as food and fuel, to services which support life by regulating essential processes such as flood risk management. The approach splits the ecosystem services in four categories (Figure 1 below).

The broad suite of benefits are categorised as 'provisioning', 'regulating', 'cultural' and 'supporting' services. The aim of the subsequent benefit valuation stage is to calculate a number by re-combining these services, which at least approaches the 'Total Economic Value' of an ecosystem. In doing this, we adopt human society orientation and turn away from the argument that habitats have intrinsic value. This is a fundamental philosophical point; bodies such as Defra and the Environment Agency represent society, not the natural world. The human community depends on the maintenance of natural habitats to continue to exist, so it is fundamentally a society-centric viewpoint. However, the beauty of 'sustainable development' as a concept is its foundation on the indivisibility of enduring ecosystem, social and economic wellbeing.

Economists who have been analysing the way in which goods, such as cars or houses, are valued will find this

Figure 1: Ecosystem Services Categories (MEA)

Provisioning services

Products obtained from ecosystems

- Food
- Fresh water
- Fuel wood
- Fibre
- Biochemicals
- Genetic resources

Regulating services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and tourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

approach all rather familiar. Generally, we do not buy a house as such, but an array of services which that house gives us: a garage perhaps, three bedrooms, the right neighbourhood with an attractive outlook. These are all attributes which affect what we are willing to pay for a piece of real estate. The big difference, of course, is that we can observe house prices. Statistically, we can correlate the price of a house with the level of these various attributes and thus impute a value to them. House surveyors do this all the time. Often, in the case of a habitat, there is no market (as such) for the services. Environmental goods and services are often public, and we share them without paying for them in a market. Thus we have a valuation problem.

We have already noted that valuation is a rather protracted and expensive affair. Thus, with tight deadlines and relatively small decisions, it is seldom worth (individually) commissioning a bespoke valuation study. The fact that such difficulties have traditionally led us to ignore the value of habitat and ecosystems altogether introduced its own distortions by externalising entirely the ecosystems supporting social welfare, and has led to bad decisions which damage the environment.

Happily, we can group habitats at risk so that we use the same numbers for similar habitats types in different analyses by transferring these as numbers, or as functions between each. This method is called 'benefits transfer'. This reduces the costs of valuation and speeds it up. The key point, of course, is that it means that there is no longer any excuse to ignore the environment in investment and policy appraisal.

Let's take coastal realignment as an example, a process which has hitherto been driven by the cost of maintaining redundant and damaged coastal defences against the combined forces of sea level rise and coastal squeeze[4]. By contrast, managed realignment is founded upon the abandonment of traditional 'hard' defences, instead allowing inundation of coastal habitat which absorbs flood surges and dissipates tidal energy emulating (or more commonly restoring) natural processes.

The case of coastal realignment

Looking at the benefits from managed realignment schemes, the main one (up to now) has generally been flood defence. The newly created inter-tidal zone acts as a natural sea defence, dissipating the energy of incoming waves and water. The new defences (if any) are set back from the sea, cheaper to build and often shorter. The saltmarsh also acts as a sponge, absorbing flood water and thus increases the storage of flood water, which would otherwise be flooding dry land.

The re-creation of inter-tidal habitat as a result of coastal realignment also has a number of other benefits, both economic and environmental. These benefits depend on the amount and the type of the habitat created and the speed of that habitat recreation. Location within the estuary and the salinity and topography of the site also matter. Taking an ecosystem services perspective, the benefits of new inter-tidal habitat also include:

- Benefits to commercial and recreational fisheries: increased fish populations as the new habitat acts as a feeding ground for juvenile fish;
- Carbon sequestration: as the new habitat builds up, it absorbs carbon;
- Water quality benefits: for example, the stripping of polluting nutrients from the water course and the absorption and/or metabolism of contaminants such as heavy metal, nutrients, toxic organic compounds, and so forth;
- Air quality benefits: it may be that inter-tidal habitats are particularly good at absorbing PM_{10}s and some ozone precursor chemicals, through dry absorption as well as the more normal processes of wet deposition. These benefits are likely to be greatest close to people in urban areas;
- Biodiversity benefits: many birds home in on inter-tidal habitats and the fish they attract. Thus there are also broader ecological, recreational and tourism benefits; and
- Regeneration benefits: the creation of new wet habitats in an urban area provides a welcome respite from the built-up city. This improvement in the sense of wellbeing often leads to regeneration of run-down areas of cities through localised habitat re-creation.

The Environment Agency Valuation Handbook[5]

The need for a systematic approach to environmental valuation in the appraisal of Flood Risk Management schemes and strategies has led the Environment Agency to

1. DEFRA, An Introductory Guide to Valuing Eco-System Services, November 2007 *http://www.defra.gov.uk/wildlife-countryside/natres/eco-actionp.htm*
2. Securing a healthy natural environment is recognised as a shared responsibility for Government through the new Public Service Agreement framework. To deliver the natural environment PSA DEFRA are committed to moving towards an ecosystems approach in policy-making and delivery of service.
3. DoE (1991) Policy Appraisal and the Environment. London: HMSO
4. Sea levels are rising on the south and east coasts because of a) global warming and b) 'isostatic' rebound. This is a development due to the rebound process following the melting of the glaciers after the last ice age in the north of Britain, where the southern and eastern land surface are submerging and the northern coasts are emerging.
5. Eftec for the Environment Agency, 'Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects', 2007

produce a handbook. It is a first attempt to provide explicit operational guidance on how to undertake habitat valuation, using an ecosystem services approach.

The method described in the handbook is one of increasing effort tailored to the needs and significance of the individual project. The handbook presents two levels of analysis:

The first cut summarises the evidence of economic value from the currently available literature and guidance on how to use this data. The ultimate aim is to give an idea of the magnitude of that evidence related to typical environmental effects associated with different scheme or strategy options.

> The newly created inter-tidal zone acts as a natural sea defence, dissipating the energy of incoming waves and water

The value evidence from the literature is summarised as pre-determined default values. These assist the user to take account of the range of environmental costs and benefits in the decision-making process. It is particularly important not to overlook environmentally valuable options which create habitat[6]. Depending on the decision being taken, the evidence generated by the first cut may or may not be sufficient. If, for instance, environmental valuation will not affect option choice then one may not wish to go further. The Handbook presents further advice to help the user decide if the first cut is sufficient.

The second cut is a step-by-step guide to benefits transfer and should be consulted when evidence from the first cut is insufficient[7]. It is more detailed, and requires more information and effort by the user. It can also be applied more widely. However, even the second cut should still be considered as a part of the exploratory process of finding profitable policy options, given the difficulties involved in transferring economic values in space across sites, habitats, groups of people and through time. The second cut also provides criteria to help the user decide whether its valuation is sufficient for their purposes or whether an original site-specific valuation study (a 'third cut') is necessary.

The default values used in the handbook are derived from meta-analysis (Woodward and Wui, 2001) up-rated to current price levels. That is, the analysis results from the survey of a body of available literature, not just one source. The data is the most appropriate we currently have, but was gathered mainly before the introduction of the ecosystem services approach. New valuations are needed for the special circumstances of the UK and to reflect developments in the conceptualisation of valuation.

The ComCoast project[8]

The ComCoast project, a trans-national EU piece of work involving the Environment Agency, sponsored three PhD students to examine: nutrient capture and carbon sequestration capabilities of managed realignment sites; fish utilisation of managed realignment sites; and the economic case for a more integrated approach to estuary management, using the results from the other two studies.

The results[9] have increased our understanding of the links between different ecosystem functions as well as the interdependency of ecosystem services. The fisheries research project highlighted the links between changes to physical habitat and the resulting welfare effect (benefits to society) of increased fish stocks for commercial and recreational fishing. The work stream on carbon sequestration and nutrient cycling showed that the more saline the habitat, the more favourable the carbon balance is likely to be. The economics research highlighted the valuable ecosystem services of saltmarshes. For instance, there is a willingness to pay for the creation of new saltmarsh in the Blackwater estuary despite the existence of other saltmarshes in the area. Respondents to the valuation survey considered saltmarsh important for amenity and recreation as well as for biodiversity. People also value access to the site (use value) and improved environmental quality (non-use value). Interestingly, people approved of saltmarshes, but not of having them too close to their homes, probably because of the nuisance caused by visitors.

Case study – Wareham

The first instance where the valuation approach was applied was at Wareham in 2006. At the western end of Poole Harbour, Wareham is adjacent to areas of international importance for nature conservation. The adjacent Frome and Piddle estuaries are lined by 50-year-old flood banks, which provide little protection against flooding. The banks protect 42 properties and 400 ha of poor quality grazing marsh. Some embankments along the River

6. Without explicit valuation, environmentally valuable options can be lost because the quantified benefits do not figure in the Cost Benefit Analysis.
7. For instance, the first cut shows that environmental valuation will affect the option choice.
8. ComCoast is a European project which develops and demonstrates innovative solutions for flood protection in coastal areas. ComCoast creates and applies new methodologies to evaluate multifunctional flood defence zones from an economic and social point of view. The aim of ComCoast is to explore the spatial potentials for coastal defence strategies for current and future sites in the North Sea Interreg IIIb region.
9. ComCoast, Work Package 2: Socio-Economic Valuation, 2007, 'Practical Application of Evaluation Techniques for a ComCoast Solution – Final summary and recommendations for Work Package 2' – Final

Piddle are subject to maintenance covenants with landowners.

A Flood Risk Management strategy for managing Wareham Tidal Banks has to address the interests of residents, landowners, nature conservation, recreation and navigation. Existing defences principally protect agricultural land. Government policy is to focus on the protection of people and property.

'Non-intervention' and 'Do Minimum' intervention options would put people and property at risk, as well as adversely affecting existing nature conservation interests, navigation and rights of way, and exposing the Environment Agency to potential litigation. On the other hand, maintaining the status quo ('Holding the Line') is unsustainable and the expenditure required would not meet Defra funding criteria.

Economic valuation of environmental services at Wareham supports the viability of a Managed Realignment approach. Limited available data enabled the relative magnitude of changes to the provision of ecosystem services across different options to be compared. Although the Wareham assessment is equivocal in terms of absolute economic benefits, it indicates a broader balance of costs and benefits associated with the proposed managed realignment and also provides information on the key areas on which further information or research is needed in order to resolve the uncertainty.

> 'The development of the UN Millennium Ecosystem Assessment has helped to unclog this impasse, by deconstructing the idea of habitat valuation. It concentrates on what services ecosystems provide, rather than trying to value them as a whole'

In conducting the Wareham study, we also found constructive engagement with a wide range of stakeholders to be essential to build understanding and support for the proposed approach, and this was helped considerably by the ecosystem valuation process.

Issues

If all of the physical effects, intermediate effects and welfare effects are included in an economic valuation, there is a significant risk of double counting of benefits, as all the physical and intermediate effects are implicitly included in valuation of the welfare effects. It is important to eliminate this double counting, whilst ensuring that all benefits are valued. One solution to this problem (practised by the ComCoast project) is to value only the welfare effects found in the immediate area and take particular care when using methods that value a number of welfare effects together, such as Willingness to Pay (WTP) surveys. For example, water quality is a welfare effect, but it also affects commercial and recreational fisheries as well as people's perception and enjoyment of the environmental quality of the habitat (another welfare effect). Therefore, if we are valuing fisheries and people's appreciation of the environmental quality of the habitat, the value of water quality as a separable and additional service should not automatically be included.

Not all ecosystem services can occur at the same time, and some conflict with others. In practice, there will often be a trade-off between two or more types of benefits achieved and that must be taken into account when valuing the benefits of schemes. For example, increased carbon burial is balanced against potential increases in methane released to the atmosphere, so the net welfare effect on rate of climate change may not always be favourable. The creation of saltmarsh habitat can generate a number of economic and environmental benefits. However, it is often the case that the creation of saltwater habitat will have a negative impact or even destroy freshwater habitat in the same area. There may be a case for deciding what type of habitat is more 'desirable', taking into account the benefits associated with each type of habitat, whether it is unique or protected, what are the objectives of each scheme, and so on.

Future developments

We need more accurate, UK-specific valuation data to support benefits transfer. Our research objective is to improve the accuracy of the benefit transfer process through original valuation studies and up-to-date science.

Ultimately, one could envisage a benefits transfer database which covers the majority of the habitats we have to cope with in the Agency, such as the inter-tidal zone, upland peat, wet woodland, reedbeds, etc. This habitat valuation database would both map the physical ecosystem characteristics of the habitat and their associated economic valuations.

The Environment Agency and Natural England have been set the challenge to create a strategy for a benefits transfer database and then apply this to more examples, beyond pilot schemes such as the Wareham analysis, thus acting as vanguard for better, more environmentally sound appraisal in the public sector.

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LAND USE MANAGEMENT IN AGRICULTURE AND HORTICULTURE AND THE CONSEQUENCES FOR WATER AVAILABILITY AND QUALITY

Farmers have an important role as stewards of the environment, says **HEATHER BARRETT-MOLD** – especially when it comes to safeguarding water quality and availability

With farming and production horticulture occupying around three quarters of UK land, the methods of production used and their effect on soil, watercourses, and water resources has a significant impact on water quality and availability. This should also be seen in context: a very high proportion of these farming and horticultural ventures are micro businesses. They don't have the options available to a larger company, adapting the work programme or taking days out for updating. Despite this, farmers and growers support and provide assistance to each other and form local syndicates, such as rural hubs, where they can get the training they need delivered in a way that suits them (NFU, 2006).

Farmers and growers use water directly for irrigation and other processes, such as the production and cooling of milk, and may also have access to watercourses on their land with animals grazing close to the water – the archetypal Constable rural scene – from which water can be contaminated by pathogens from excreta. Indirect impacts may result from run-off from the land of excess nutrients, pesticides or veterinary products, such as sheep dips, which will work their way into aquifers and rivers. Depending on the cultivation of the soil, varying amounts of silt will wash off during flooding, possibly having detrimental effects on spawning grounds. The potential for impact cannot be underestimated.

Agriculture intensified during and since the Second World War, with the European Common Agricultural Policy placing further harmful pressures on the environment. Concerns in the 1970s and '80s led to increasing legislation and environmental protection. Farmers and growers, as ever, have in general responded to the changing agenda and, as a result, pollution from point sources has declined with the result that more attention is now being paid to diffuse pollution. Raised concentrations of agriculturally derived pollutants, such as nitrate and phosphorus, can have serious effects on the health and diversity of our fresh and marine waters. Water quality has improved since 1990, in part due to better control of slurry as well as considerable investment in sewage and industrial wastewater treatment. Diffuse pollution of water is the next target for action.

Given the high proportion of land devoted to agriculture and horticulture, it may not be surprising that these industries are the source of most of the silt entering catchments, along with 40-50% of the phosphates and around 70% of the nitrogen in the water. Although this may not be disproportionate relative to land area, it still needs to be addressed (Defra, 2008). By 2015, the Water Framework Directive will require an integrated approach to managing water quality and quantity across whole river catchments. This Directive results in targets for the UK that must be achieved by 2015 to avoid considerable financial penalties (Defra, 2007).

As well as raising the silt content of watercourses and causing physical problems, soil erosion is one of the major routes for pollution by phosphorus which is largely found associated with particulate matter rather than in dissolved form. Soil erosion can result from lack of vegetation cover, vehicle compaction of soil, too fine a seedbed, poaching of grazing land, inappropriate timing or orientation of tillage, and the breakdown of watercourse banks. With climate change and its probable extremes of weather events, all of these aspects of soil erosion are likely to be exacerbated.

'With farming and production horticulture occupying around three quarters of UK land, the methods of production used and their effect on soil, watercourses, and water resources has a significant impact on water quality and availability'

All farmers in receipt of the Single Payment must maintain their soils in good agricultural and environmental condition (GAEC). As part of meeting the GAEC standard, farmers must complete a Soil Protection Review. Over 99% of the agricultural land in England and Wales is subject to such a review. In addition, more than 1.5 million hectares of farmland is managed under the Entry Level Environmental Stewardship scheme (NFU, 2006; University of Reading, 2008).

The Defra Catchment Sensitive Farming initiative aims

> Water is as essential for agriculture and horticulture as it is to all aspects of life. Nationally, the balance between supply and demand is under pressure

to achieve land management that keeps diffuse emissions of pollutants to water at levels consistent with the ecological sensitivity and uses of rivers, groundwaters and other aquatic habitats within target catchments through good farm management of the soil, stock and water. Though currently a targeted pilot scheme, the Catchment Sensitive Farming initiative may be extended in the longer term. The scheme fits best within a whole farm policy, which provides the basis for efficient and profitable production that is economically viable and environmentally responsible. Integrated Farm Management (IFM) is an approach that combines the best of traditional farming methods with modern technology, allowing farmers to manage their farms in an informed and professional way. Under IFM, for example, pesticides and fertilisers are only used when absolutely necessary to keep animals and crops healthy. IFM aims to ensure the highest standards of food production with the minimum environmental impact (LEAF, 2008).

The Landcare Project, a Defra-funded review of land care which commenced in 2005 to assess the extent of activity to reduce diffuse water pollution across England, seeks to evaluate the factors that characterise a successful project. The key lessons learned were then applied to help Defra establish best practice, to inform current and future projects, and to identify areas where Catchment Sensitive Farming (CSF) delivery could add value. There were 60 projects included in Landcare, costing in excess of £35.5 million. All of the projects engaged with farmers at some level; many were advisory and the majority funded workshops, demonstration farms and one-to-one advice. One-to-one advice was found to be the most effective way of engaging with farmers, ultimately persuading them to change farming practices to reduce diffuse water pollution. Evaluation from the projects showed farmers were more willing to work with trusted sources, such as local agronomists, FWAG and River Trusts (Horsey, 2006).

In the Hampshire Avon Landcare Project, a baseline study was undertaken to determine the impacts of current land management practices. Problem areas were identified for farmer advice and then demonstration farms were established in those high risk areas to show how timings and depths of cultivations affect crop growth and run-off/erosion rates. Around 150 farmers from all sectors were involved. Individual soil risk assessments were made at each farm involved in the project. Practical workshops were set up for both farmers and advisors. Changes in farm behaviour and practices and river pollutant were monitored. This project resulted in a reduction in localised flooding, mud on roads and loss of topsoil, and farmers made better use of good manures, resulting in savings on artificial fertiliser. In addition, there was an improved yield for winter cereals following the reduction in soil compaction. As a probable consequence, fisheries in this catchment are currently on a steady upturn in numbers and water quality has also improved in one high-risk sub-catchment (Horsey, 2006).

Water is as essential for agriculture and horticulture as it is to all aspects of life. Nationally, the balance between supply and demand is under pressure. Water is used for a wide range of agricultural and horticultural activities, from irrigation and livestock drinking to milk cooling and machinery washing (Environment Agency, 2007). Fifty-eight per cent of farmers in a recent NFU survey said that they were affected by the 2006 drought, with most experiencing a decline in crop production or quality (NFU, 2007). Farm water audits are recommended through Waterwise, the Environment Agency initiative, including quantification of the various uses of water and calculation of real costs. Sources used to supply this water include: abstraction from rivers, streams, canals, springs or boreholes; on-farm ponds or other winter-stored water; water drunk by animals from non-metered sources; and re-used water, such as plate cooling water or harvested rainwater. The real cost of water to farmers and growers not only relates to the direct costs of water but to pumping, treatment and disposal costs as well as any capital costs of equipment (Environment Agency, 2007; NFU, 2007).

> 'This project resulted in a reduction in localised flooding, mud on roads and loss of topsoil, and farmers made better use of good manures, resulting in savings on artificial fertiliser'

East Clyffe Farm, a 330 hectare livestock farm, was the winner of the Environment Agency Water Efficiency Awards in 2003. The winning project was devised and undertaken by the farm owner to reduce water use and wastage and to return surplus rainwater back to the chalk rather than allowing it to go to waste in the drains, based on observations of water flow and executed using existing industrial machinery at a low cost. Tree planting, beetle banks and 'sleeping policemen' helped to reduce run off and, as a result, more water was made available to recharge local aquifers. Benefits from the East Clyffe Farm scheme include a reduction of abstraction rates to below 10,000m^3 per annum, thus removing the need for an anticipated increase in abstraction licence quantities, as well as reductions in soil movement in the pig field, erosion where sheep eat stubble turnips and the incidence of flooding of farm buildings, land and poultry houses (Environment Agency, 2008).

Capture of rainfall and storage in reservoirs is another method that is used in parts of the industry to conserve water for times of need, as well as contributing to a reduction in flooding and improved maintenance of waterways. At Pershore College, Worcestershire, the commercial nursery recycles water collected from the roofs of college buildings and subsequently uses it to irrigate the nursery stock. A system of reservoirs and underground piping is in place to store and distribute this water. In 2007, this horticultural enterprise used about 7,000m^3 of water a year, of which 2,500m^3 was collected from the roofs having previously been abstracted from the river. This was limited by the size of the tanks at 1,500m^3 but plans were in place to increase this storage and to put in place a treatment reed bed (EAUC, 2007).

There are direct and indirect benefits to the public of a better-informed and more responsible approach to water management. In general terms, the more care farmers and growers take of the local environment, the more it can be better valued and understood by all those who visit the countryside or live and work in the area. In addition, there is more encouragement for people to exercise and improve their health through their access to the countryside and its waterways. With a reduction in point source and diffuse pollution, biodiversity will improve. Maintaining waterways by protecting water as a resource will also protect that habitat and its species. Improved soil structure and water flows will reduce the potential for flooding. A significant indirect benefit is the reduction in the use of artificial fertilisers and the high energy input in their manufacture and, as such, a lesser contribution to climate change.

As the major landowner in the UK, farmers and growers cumulatively not only have the responsibility to produce high quality, safe food at a reasonable cost, they also have an important role as stewards of the environment. Their work is closely bound up with tourism and our cultural heritage. The positive response to such a big responsibility must continue.

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UNITED UTILITIES SUSTAINABLE CATCHMENT MANAGEMENT PROGRAMME (SCaMP)

Agreements between tenant farmers and their landlord, a major utility company, are promising both ecological and economic benefits. **MARTIN MCGRATH** and **DAVID CRAWSHAW** explain how

United Utilities (UU, one of the UK's largest multi-utility companies) is a major landowner in the North-West of England, with 57,800 ha of land of which 56,000 ha is catchment land (i.e. land primarily managed for water capture and not that associated with water and wastewater operational sites and farm infrastructure). Much of this land is of high conservation importance, but over 50% of it was classified by Natural England as in poor condition and in need of urgent remedial action. The Sustainable Catchment Management Programme (SCaMP), which received funding by government agreement under the 2004 review of water prices, is aimed at securing management of two key areas of land which will protect and improve water quality, enhance biodiversity and ensure a sustainable future for the company's agricultural tenants.

SCaMP was developed in association with the Royal Society for the Protection of Birds (RSPB), which will be a key partner with United Utilities in delivering the work. The programme has attracted an unprecedented level of interest and support, both regionally and nationally, with many individuals and organisations visiting and expressing support. United Utilities has worked closely with Natural England and the Forestry Commission in making sure that what is proposed under SCaMP will help achieve multiple benefits and is consistent with their local and area objectives and plans.

SCaMP involves working with tenant farmers, regulators and stakeholders in the upland water catchment areas of Bowland and the Peak District to develop and implement whole farm plans. These plans identify the farm infrastructure improvements necessary to support sustainable land management practice; implement low impact farming systems; restore catchment hydrology; and re-create habitats for a range of threatened wildlife. SCaMP looks to support our tenant farmers in gaining access to agri-environment grants which ensure that the programme is both environmentally and economically sustainable. The programme identifies specific benefits for the protection and restoration of designated wildlife sites, wider wildlife enhancement, water quality protection and improvement. These are outlined in detail below.

The benefits of SCaMP

SCaMP yields a range of benefits ranging from nature conservation, particularly for statutory Sites of Special Scientific Interest (SSSIs) and Biodiversity Action Plans (BAPs), and also improvements to water quality, agricultural practice and catchment management.

Benefits to SSSIs

Nearly half of UU's catchment land (45% of total catchment land holding) is in three National Parks. Some 30% of this area is covered by various SSSI designations. In total, UU owns land in 54 different SSSIs including nine Special Protection Areas (EU Birds Directive) and 19 Special Areas for Conservation (EU Habitats Directive). Some 23% (4,032 hectares) of our SSSI land is in unfavourable and declining condition. Around 29% (5,120 hectares) is in unfavourable and 'no change' condition, and about 36% (6,247 hectares) is in unfavourable and recovering condition.

- The Sustainable Catchment Management Programme (SCaMP) aims to ensure that all the land currently in unfavourable condition reaches the Government's SSSI target of 95% in favourable condition by 2010, and all SSSI land is protected from possible future deterioration.

Benefits to UK BAP priority habitats and species

We also anticipate substantial benefits to Biodiversity Action Plan priority habitats and species occurring within our land holdings, including:

- 100% of upland oak woodland brought under sympathetic management, and a 10% increase in area;
- 100% of upland hay meadow brought under sympathetic management, with a 100% increase in area;
- an increase in the area of blanket bog (through restoration of degraded systems) of 10%;
- 100% of wet woodland brought under sympathetic management, with an increase in area of 10%;
- 100% of purple moorgrass and rush pasture brought under sympathetic management with a 5% increase in area;
- 100% of upland heathland brought under sympathetic management and 10 hectares of new habitat.

Incorporating these benefits into farm plans and applications for agri-environment support schemes has been important in securing funding.

Benefits to water quality

United Utilities also anticipates improvements in three areas related to water quality: microbiology; soil erosion; and water colour.

- Microbiology – The key issue with regard to public health is contamination of raw water by faecal material leading to unacceptable levels of cryptosporidium and/or coliforms. SCaMP plans include improved muck handling facilities and stock exclusion from vulnerable watercourses by fencing, whilst also providing protection for new broadleaf woodland. Further improvement is also planned to winter grazing regimes and removal of high risk activities, such as lambing, off catchment. Many of the improvements involve reduction of overall stock densities together with provision of stock housing to allow over-wintering of stock. These changes are in line with the 'Drinking Water Safety Plan' approach promoted by the Drinking Water Inspectorate.
- Water colour – Over the last 30 years or so, and particularly in the last 15, the levels of colour in some of our raw water supplies have risen by a factor of four. This is as a result of flushing out of humic materials from moorland areas damaged over a long period of time by a combination of moorland drainage, atmospheric pollution, localised overgrazing and moorland fires. The extra colour is difficult and costly to treat and is undesirable from a public health aspect.
- Soil erosion – This is closely linked to the water colour issue, with similar causes. Erosion products such as particles of soil and peat find their way into our reservoirs where they can settle, thus using up valuable capacity. If they find their way into treatment plant they simply inflate costs.

  Soil erosion also impacts upon biodiversity. Restoration measures and improved catchment management are integral to protecting habitats and associated biodiversity.

Benefits for farmers

With changes to the EU common agricultural programme support mechanisms and the introduction of new agri-environment schemes, it has been a difficult time for farmers to plan ahead and formulate business plans. We believe that SCaMP has offered a real benefit to farmers in the form of clear long-term objectives and investment in farm infrastructure to achieve them.

We believe that viable farm income is one of the key components in the complex jigsaw of sustainable catchment management, and so we are also offering support and advice to assist farmers in securing agri-environment grants and implementing farm plans. SCaMP has offered farmers a real opportunity to resolve some uncertainties and plan for their future.

Benefits as a template for catchment management

The final benefit of SCaMP is as a template, allowing us to increase and quantify our understanding of the outcomes of more sustainable catchment management for:

- Improving water colour;
- Sustaining farm incomes;
- Reducing cryptosporidium risk;
- Reducing long-term costs to water customers;
- Reducing flood risk downstream of improvements; and
- Enhancing aquatic, wetland and terrestrial biodiversity.

To this end, we have in place an extensive monitoring programme to see the effects of land management changes contained in the farm plans on vegetation, hydrology and water quality.

The structure of the programme: whole-farm action to restore catchments

Current farm practice and its environmental impacts

Farms owned by United Utilities and let out to tenant farmers are predominantly livestock enterprises, mostly hill ewes, with some farms also running small beef suckler herds. Traditionally, stock numbers have been dictated by subsidy levels rather than the environmental carrying capacity of the land. In particular, headage payments have encouraged overgrazing, and the resultant conversion of heather moorland to species-poor grassland.

The traditional style of agriculture and topography of these upland holdings also mean that large numbers of livestock have generally been over-wintered on the moors, staying out during the wettest months of the year, when their impact on blanket bog, heather moorland and soil structure is greatest.

Drainage of blanket bogs and moorland, from historic water gathering and for agricultural improvement, has further exacerbated habitat loss and erosion. This has resulted in water quality problems from increased colour, as oxidised peat is released into grips and drains, and eventually into the rivers and reservoirs that provide public water supply.

Finally, in order to sustain these livestock numbers on the moor, the management of grassland on the adjacent 'in-bye' has frequently intensified. This has led to the conversion of traditional upland hay meadows to silage production, which has also put water quality at risk. Risks to water quality are further increased when large numbers of livestock are held on relatively small areas of in-bye grassland during lambing, shearing and tupping.

What does this mean for farmers?

Reduction and reversal of these impacts require a number of key changes to land management. These are:

- Achieving appropriate stock densities and types;

- Removal of stock from sensitive land during vulnerable times of year;
- Reversal of grip-drainage ('grip-drainage' is the drying out of peat by drainage channels, or 'grips', cut into the peat);
- Restoration of damaged habitats (for example, through direct reseeding of heather and other dwarf shrub species); and
- Recreation of species-rich grasslands and their sensitive management.

In order to achieve a viable farm business compatible with, and capable of, supporting and sustaining these changes to land management, the following changes, where appropriate, are likely:

- Adequate winter housing, to allow animals to be taken off the moor during winter;
- Enhanced farm waste management facilities, to minimise and handle the wastes generated by over-wintering stock indoors;
- Significant enhancement of infrastructure to control and manage stock, e.g. new fencing to protect watercourses;
- Enhanced and improved sheep dipping facilities;
- Appropriate diversification to ensure adequate farm incomes; and
- Maximising the environmental and economic benefits of new environmental subsidies.

We believe that these changes to the whole farm business are necessary to achieve appropriate management of SSSIs, to deliver benefits for Biodiversity Action Plan habitats and species, to secure farm incomes, and to protect and enhance water quality.

The Whole Farm Unit

Designated and non-designated land.

The majority of farms (though not all) within the two areas have some components of SSSI. (The ratio of SSSI to non-SSSI land varies between farms.) Typically, the area of the farm notified as SSSI will be the part above the moorland edge (due to the historical patterns of notification practice). The whole area of the farm and its associated grazing, including in-bye grasslands that may be outside SSSI boundaries, are implicated in securing favourable condition on the SSSI. This is because:

- The integrity of the SSSI itself, particularly the blanket bog components, are dependent on functioning hydrology. This is because the impacts of drainage must be addressed across the whole site if erosion and water loss affecting key habitats is to be reversed. This will involve action across the whole farm.
- The reductions in stocking levels and changes in drainage practice required on SSSI land can only be achieved on farms that become more extensive but remain viable. The whole farm must be adapted to a more extensive management regime, as described above.
- Many key 'interest features' of the SSSI and key BAP species will use the full range of habitats on the farm to complete their life cycle. For example, twite – a UK Biodiversity Action Plan priority bird species – breeds in mature heather on the SSSI (or SPA) but does all its feeding on surrounding farmland on seeds provided by species-rich grasslands.
- The beneficial effects of reducing sheep numbers on SSSIs may well be negated by a corresponding increase on non-SSSI land unless the two components are treated as an integrated whole. If they are not managed as an integrated unit, water quality and BAP targets outside the SSSI will not be met.

Whole Farm Plans – the full package

The core of the current scheme is therefore a whole farm plan for each agricultural business, including:

- improvements and changes to farm infrastructure to promote viable extensive farming in the future;
- a range of direct management interventions to deliver specific benefits for the SSSI and BAP features of interest on each farm, building on these core changes; and
- a comprehensive review of predicted agricultural incomes under changed management practices and new agri-environment subsidies, to ensure future farm viability.

The success of the Sustainable Catchment Management Programme has hinged upon agreement on the individual Whole Farm Plans between UU and tenant farmers, and these plans being translated into agri-environment grant support.

SCaMP implementation commenced in 2005. Early indications from biodiversity surveys and monitoring of water quality and hydrology are that this ecosystem-based restoration programme is yielding promising results. We will have to wait for some time, taking account of the wide variability seen in ecosystems and environmental trends, to be assured that the progress is sustained. However, UU is committed to shifting its efforts from retrospective and expensive problem management at 'end-of-pipe' and 'end-of-catchment' towards interventions at source yielding multiple and simultaneous ecological, economic and social benefits.

There is a great deal of interest in the pioneering work of SCaMP from across the world – from South Africa to the USA, Australia and elsewhere – for lessons in how water resources may be managed more sustainably by placing ecosystems and ecosystem services at the heart of management decisions and interventions.

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SOUTH AFRICA'S JOURNEY TO EQUITY, SUSTAINABILITY AND EFFICIENCY

BARBARA WESTON and **DEREK WESTON** describe the key role of water in South Africa's transition to sustainability

South Africa's quest for a just and sustainable future, emerging since abandonment of apartheid in 1994, is an inspiring tale often told. What is less often related is the pivotal role of water in securing this complex and long-term aspiration, and the crucial role of ecosystems in the production of water to provide for diverse human needs.

Dry lands

South Africa is an arid country, with one of the lowest conversions of precipitation into river run-off seen anywhere in the world. Water is not only scarce but is also unevenly distributed, due to geographic, climatic and social factors. Per capita water consumption amongst the nation's 14 million black people is less than a twentieth of that of the typical white South Africa, and a study by Cullis and van Koppen (2007) in the water-stressed Olifants Water Management Area applied the Gini Coefficient to the distribution of water resources discovering a ratio of 0.96. (The Gini Coefficient is a measure of statistical dispersion, prominently used to measure inequality of income or wealth distribution defined as a ratio of between 0 and 1. Zero corresponds to perfect equality while 1 corresponds to complete inequality wherein one person has all the income whilst everyone else has zero. A Gini Coefficient of 0.96 in the Olifants WMA implies that 99.5% of rural households are entitled to use only 5% of available water.)

Access to a limiting resource of any kind – be that gold, oil, trees or armaments – is a surrogate for power, wealth and influence. In an arid country, water is not only a key limiting resource but is also essential for supporting basic health and livelihood requirements as well as additional economic and cultural uses.

The National Water Act

Early on in the democratic accession of the new government in 1994, priority was given to revision of the nation's water and broader environmental laws as a fundamental underpinning of South Africa's policy transition to sustainability and equity.

Unlike many sustainable development initiatives in affluent nations, historic inequities and the priority now ascribed to empowering historically disadvantaged communities raises the profile of social issues beyond a simple focus on collective stewardship in the management of natural resources. Instead, support for basic human needs takes a justifiably high priority alongside ecosystem management, maintained by technological solutions in a nation where economic progress is already substantially supported by extensive dams, inter-basin transfers and other heavy water engineering. Indeed, 100% of the water needs of the Johannesburg-Pretoria conurbation, the 'engine' of South Africa's economy, is supplied by transfers of water from outside the drainage basin within which these cities lie. Any conception of 'sustainable water supply' is necessarily complicated by historic, ethical and geographical exigencies. With water resources already stressed and often over-allocated, bringing water services to an increasing proportion of the population requires innovative thinking.

The process of development of South Africa's novel water law and its partner environmental legislation – the National Water Act (NWA) (Republic of South Africa, 1998a) and the National Environmental Management Act (NEMA) (Republic of South Africa, 1998b) – is in many ways as important as the letter of the resulting legislation. Both entailed a long process of engagement with stakeholder groups, including not only 'experts' but also many sectors of society including the formerly disenfranchised, to establish sets of principles that should inform the iterative process of drafting.

The fundamental principle that guides the NWA is that water is a national resource, owned by the people of South Africa and held in custodianship by the state (Section 3 of the NWA). This principle removed overnight the historic rights-based allocation of water in place during the apartheid era, with its heavily pro-white and pro-agricultural bias, instead passing total control over the utilisation of the resources to the state on behalf of the people.

Three of the central principles within the NWA are equity, sustainability and efficiency. So fundamental are the protection of resources to support the basis needs of all people and of the ecosystems which provide water-related ecosystem services that these are enshrined in 'the Reserve', supported by requirements for greater efficiency in the use of water resources.

The Reserve

Section 16 of the NWA establishes the concept of the 'Reserve' to protect the national resource of water, constituting perhaps the most significant innovation within the Act. The Reserve seeks to protect the allocation of adequate water, in terms of quantity and quality, to support both human needs and ecological integrity and functioning. These are framed as the 'basic human needs' and 'ecological reserve' sub-components of the Reserve.

The 'basic human needs' element of the Reserve relates to the basic right of all people to a minimum amount and quality of water for living and daily tasks (drinking, washing, sanitation, etc). This is set at 25 litres per person per day, accessible within 200 metres of homes. Targets are set by the national government for each stretch of river across the country, based on population data.

The 'ecological reserve' relates to the minimum quantity and quality of water necessary for maintaining ecosystems at an agreed target quality level, protecting (or in some cases restoring) their integrity and the continued production of a range of ecosystem services. A raft of methods have been devised to establish, set and monitor quality levels for every reach of river across South Africa, securing benefits for society. The 'ecological reserve' too is set by national government in order to ensure integrity.

Establishment of the ecological reserve remains problematic for both technical reasons and also ones of perception. Like many instream flow requirement (IFR, also known as 'ecological flows') schemes in place or under development around the world, there is a perception that this water is allocated for 'nature' in competition with the needs of people. This rift in understanding needs to be resolved.

Water, wildlife and people

Part of the misperception relates to nature conservation in apartheid South Africa having frequent racist implications or consequences. For example, nature or hunting reserves were often established by the forced clearance of poor and vulnerable people and their resettlement into sub-optimal environments. Consequently, there is often a sense of white elitism when the subject of nature conservation is addressed.

The 'ecological reserve' is, however, a different order of legal instrument. While the unfortunate legacy perception is that it allocates to nature precious water required by people, the reality is that it seeks to safeguard the fundamental role of aquatic ecosystems in supporting social wellbeing. It is, after all, the various habitats within catchment ecosystems that intercept, store and purify water, buffer flows, recharge groundwater, renew grazing and croplands, form culturally- and spiritually-important landscapes, produce fish, waterfowl, reeds and floodplain timber and, in many other ways, provide the primary resources essential for human wellbeing. This more informed conception of the 'ecological reserve' – as a safeguard of ecosystem services beneficial to society rather than as a competitor for scant resources – needs to be amplified in order to increase understanding and acceptance of the need for all elements of the Reserve. In reality, the 'basic human needs' and 'ecological reserve' elements of the Reserve are merely different facets necessary to secure social welfare and wellbeing.

Beyond the Reserve, further water allocations are set nationally to cater for international agreements, inter-basin transfers, strategic needs and future development. Beyond this minimum, remaining water may then be allocated to municipal, industrial and agricultural uses for the achievement of the greatest public good and environmental values.

Devolution of authority

It is the intent of the NWA to establish Catchment Management Agencies (CMAs) on a supra-catchment basis, accountable ultimately to the Minister but steered by a board membership representative of the disparate stakeholder groups needing to share and protect precious water resources. These are to be supported by less formal organisations at catchment and sometimes sub-catchment scale with appropriate stakeholder representation to determine how best to share water within catchments.

CMAs will have powers to charge for water use in order to finance their activities, and with time will receive increasing levels of authority from the Department for Water Affairs and Forestry (DWAF). We are still early in this rather slow process of institutional transformation, which is not the central theme of this paper but which will nevertheless be critical to delivery of equitable, sustainable and efficient water services. It is, however, clear, that the vision of future water provision can not be achieved by the old paradigm of 'expert' decision-making, overlooking the central importance of ecosystem services in the production of water and a range of other benefits to society, or of yet more dams and pipes in already stressed catchments. New models of stakeholder engagement, adaptive governance and management, alternative and appropriate technologies, and a broad range of other innovations will be required in this time of flux for South Africa.

Making the transition

Both the NWA and NEMA are framed in terms of key provisions of South Africa's constitution, seeking simultaneously to address equitable development and environmental protection implemented through co-operative governance. Both also seek delegation of decision-making to ensure that citizens are granted opportunities for effective involvement in democratic and economic development. 'Environmental justice' is central to both the constitution and the frameworks of both Acts.

South Africa's transition in water management seeks simultaneously to ensure sustainability across the competing demands of economic development, ecological resilience, and equity including empowerment of the poor. This world-leading 'experiment' is paralleled by a wider shift in thinking about water management elsewhere across the globe.

The process is very far indeed from being complete in South Africa. Institutional capacity remains a major obstacle in terms of people, financial resources and the available skill base. However, international donor efforts are trying to support South Africa through this transitional period.

What remains crucial is that the governing principles – democratic participation, adaptive management, appropriate reform of institutions and, at their heart, principles of equity, sustainability and efficiency – remain in the driving seat during this necessarily long period of transition. Globally, South Africa is plotting a new pathway from which other nations may learn and that they may elect to follow.

At its heart are the environmental and ecological processes that produce the diverse 'ecosystem services' – from fresh water supply to waste assimilation, regenerated productive land and other economic resources, valued landscapes, ecological integrity and many more besides – upon which current and future human wellbeing and prosperity depend.

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IES: NEW MEMBERS

The Institution of Environmental Sciences is pleased to welcome the following new members and re-grades:

Androniki Apostolakou	Environmentalist	Af
Kamran Basharat	Community Support Worker	A
Paul Beckett	Director	M
Gemma Berridge	Environmental Consultant	M
Fergus Boughton	Air Quality Consultant	A
Graham Boultbee	Graduate Geo-Environmental Engineer	A
Laura Brearley	Senior Environmental Scientist	M
Nicholas Brown	Senior Environmental Consultant	M
Timothy Cave	Renewable Energy Consultant	A
Carol Chan	Air Quality Consultant	M
Adam Collinge	Landscape Architect & Ecologist	A
Sarah Cook	Environmental Engineer	M
David Deakin	Senior Environmental Consultant	M
Edward Dearnley	Policy Officer – Air Quality & Climate Change	M
Simon Elliott	Associate Environmental Planner	M
Dafydd Evans	Research Assistant	A
Patrick Froggatt	Air Quality Consultant	M
Laura Frost	Sustainability Consultant	A
Paul Giesberg	Independent Consultant	M
Stephen Gray	Graduate Environmental Scientist	A
James Griffin	Principal Development Control Officer	M
Carl Hawkings	Technical Director	M
Polly Hill	Student (PhD Oceanography)	Af
Nicola Hyslop	Graduate Engineer	A
Christina Iball	Air Quality Consultant	M
Lance Ingrams	Assistant Landfill Manager	A
Waheed Iqbal	Graduate Trainee	A
Evelyn Ketibuah	Harrison Group Environmental Ltd	A
Jon Kirkpatrick	Associate Director – Sustainability	M
Emma Lunt	Environmental Scientist	M
Sarah Martin	PhD Student	Af
Nicholas Mitchard	Senior Environmental Scientist	M
Dipalee Patel	Senior Geo-Environmental Engineer	M
Caryl Pollard	Assistant Sustainability Consultant	A
Philippa Powell	Environmental & Sustainability Consultant	M
Fiona Prismall	Air Quality Consultant	M
John Rhoades	Scientific Officer	M
Guy Richardson	Assistant Environmental Scientist	A
Benjamin Rose	Environmental Protection Specialist	M
Dominic Ryan	Air Quality Consultant	A
Giancarlo Serra	Principal Environmental Enforcement Officer	M
Ji Shi	Air Quality Technical Advisor	F
Robert Showell	Contaminated Land Manager	M
Stuart St John	Nuclear Environmental Consultant	A
Sara Turnbull	Sustainability Consultant	A
Julia Warren	Senior Environmental Scientist	M
Jason Weeks	Aquatic Health & Hygiene Business Development Manager	M
Ian Whitwell	Associate	M
Antony Wiatr	Environmental Consultant	A
Francis Williams	Associate Director	M
Jamie Williams	Environmental GIS Consultant	A

KEY: **F = Fellow** **M = Member** **A = Associate** **Af = Affiliate**

WORKING FOR WATER

GUY PRESTON and **MARK EVERARD** look at the battle to protect water supplies by stemming the tide of invasive alien species

South Africa is emerging from an apartheid history into democratic governance, to which a novel model of equitable, sustainable and efficient use of water is of critical importance within an arid and increasingly climate-challenged landscape. Water, its availability and equitable sharing, is a critical limiting factor to both economic and social wellbeing. Working for Water is an innovative South African programme simultaneously delivering water quality and water quantity, biodiversity and social benefits, with the indivisible relationship between water, ecosystems and people at its heart.

Water in an arid landscape

From the 1600s, waves of European colonisers incrementally appropriated South Africa's scarce water resources to create fertile farmlands and industrial enterprises in an otherwise arid landscape. Exclusive access to water was progressively cemented in legislation, such as the Irrigation Act of 1912 which stated that water constituted the sole property of the owner of the land on which it rose and that 'he can do whatsoever he pleases with it and neither the owners of lower-lying land nor even the public can claim to be entitled to make any use at all of that water'. Differential access to water was a key factor deepening social divisions during the apartheid era, when white-only elections, white-only jobs, white-only land and, effectively, white-only access to water were progressively legalised. By the time apartheid ended in 1994, clean, potable water was piped into the homes and farms of virtually all five million white South Africans, whilst approximately half of the nation's black population of some 35 million lacked access to safe water.

The quality and quantity of water running off South Africa's catchments was also compromised significantly by waves of colonisation by invasive alien plant species. In many localities, alien invasive scrub and trees such as Australian black wattle, European and American pines and Australian eucalyptus have out-competed native vegetation. Some of these invasive alien species have a far stronger demand for water than the native species they have displaced, exacerbating the pressure on potentially water-stressed catchment landscapes. Literally hundreds of other alien species have found a root-hold in South Africa with uncertain and unpredictable consequences.

Invasive alien species – plants, animals and microbes introduced from elsewhere which out-compete indigenous species – are recognised as causing billions of Rands worth of damage to South Africa's economy every year, representing the single biggest threat to the country's biological biodiversity and a significant risk for its water security and the productive use of land. They also intensify the impact of fires and floods as well as increasing soil erosion. Current estimates suggest that 350 introduced plants should be classified as invasive in South Africa, covering about 10% of the area of the country today with the problem growing at an exponential rate.

There are numerous scientific studies of the scale of loss of water through alien vegetation. The most widely-accepted estimate is that invasive alien species could use 17% of mean annual runoff (MAR) if left to invade, though one (albeit contested) paper claims a staggering 91% reduction in MAR in the Namaqualand coast of the Western Cape. This effect is due largely to increased evaporative loss by invasive trees compared to native herbaceous vegetation (Dye and Jarmain, 2004) with rooting depth a key factor in depleting the water recharge of former rangelands (Seyfried and Wilcox, 2006).

Rebuilding the links

Historically, there has been a significant disconnection between social equity and biodiversity considerations in South Africa. This legacy adds complexity to communication of the importance of ecosystems in support of human wellbeing. Nevertheless, recognition of the direct connections between healthy people, healthy ecosystems and a healthy economy, and policies and actions founded upon this linkage, are some of the more significant principles embodied in the many reforms within South Africa following the fall of apartheid. This includes development of a set of novel water laws and policies that, though mainly enacted in 1998, are still regarded as world-leading today.

Arid landscapes amplify the importance of the inexorable linkage between the environment, the economy and social justice. As Kadar Asmal (South Africa's first post-apartheid Minister for Water Affairs and Forestry) put it, 'Water is access to power' (Kenny, undated). By making access to basic water a human right, allied to creation of a market for additional water use, South Africa's innovative water laws resolve human rights with market-based conservation tools while simultaneously respecting the capacity of catchments to provide that water.

The Working for Water programme

The National Water Conservation Campaign, established early in the democratic era, comprised a program using conservation methods to increase water availability. These included the clearance of invasive species from river catchments, as evidence had suggested that the removal of water-hungry vegetation could prove more cost-effective than the construction of infrastructure such as dams or filtration plant.

One of the initiatives spinning off from this campaign was the Working for Water (WfW) programme, an innovative scheme providing jobs for the least advantaged in society to control problematic invasive plants. WfW is making a substantial contribution simultaneously to supply of water coincident with wider ecosystem protection, job creation, poverty alleviation and training in vulnerable catchments within South Africa.

> ‘Working for Water is an innovative South African programme simultaneously delivering water quality and water quantity, biodiversity and social benefits, with the indivisible relationship between water, ecosystems and people at its heart’

WfW was established in 1995 with a budget of 25 million Rands. Its mission statement objectives seek, through the control of invading alien plants, to: enhance water security; improve the ecological integrity of natural systems; restore the productive potential of land; invest in the most marginalised sectors in South Africa and enhance their quality of life through job creation; and develop economic benefits from wood, land, water, and trained people. So successful has the scheme become that today it is one of the biggest conservation programmes in the world with an annual budget approaching R600 million (including the KwaZulu-Natal Invasive Alien Species Programme, or KZN IASP).

The focus of the programme is combating invasion by alien plant species, addressing all species as well as the more water-thirsty ones, using labour-intensive methods that lend the programme its strong focus on social development. This integration of environmental concerns with social justice issues has led to WfW gaining international recognition.

WfW is government-led with three core departmental partners – Water Affairs and Forestry (DWAF which is the lead agency), Environmental Affairs and Tourism (DEAT) and Agriculture (DoA) – as well as partnerships with provincial governments and local communities to which it provides jobs, and additional partnerships with government agencies, NGOs, the private sector and civil society. The bulk of the funding comes under the banner of the government's Expanded Public Works Programme (EPWP), underlining the programme's contribution to tackling poverty, employment and training quite apart from the indirect contribution of removing alien plants to alleviating poverty and unemployment.

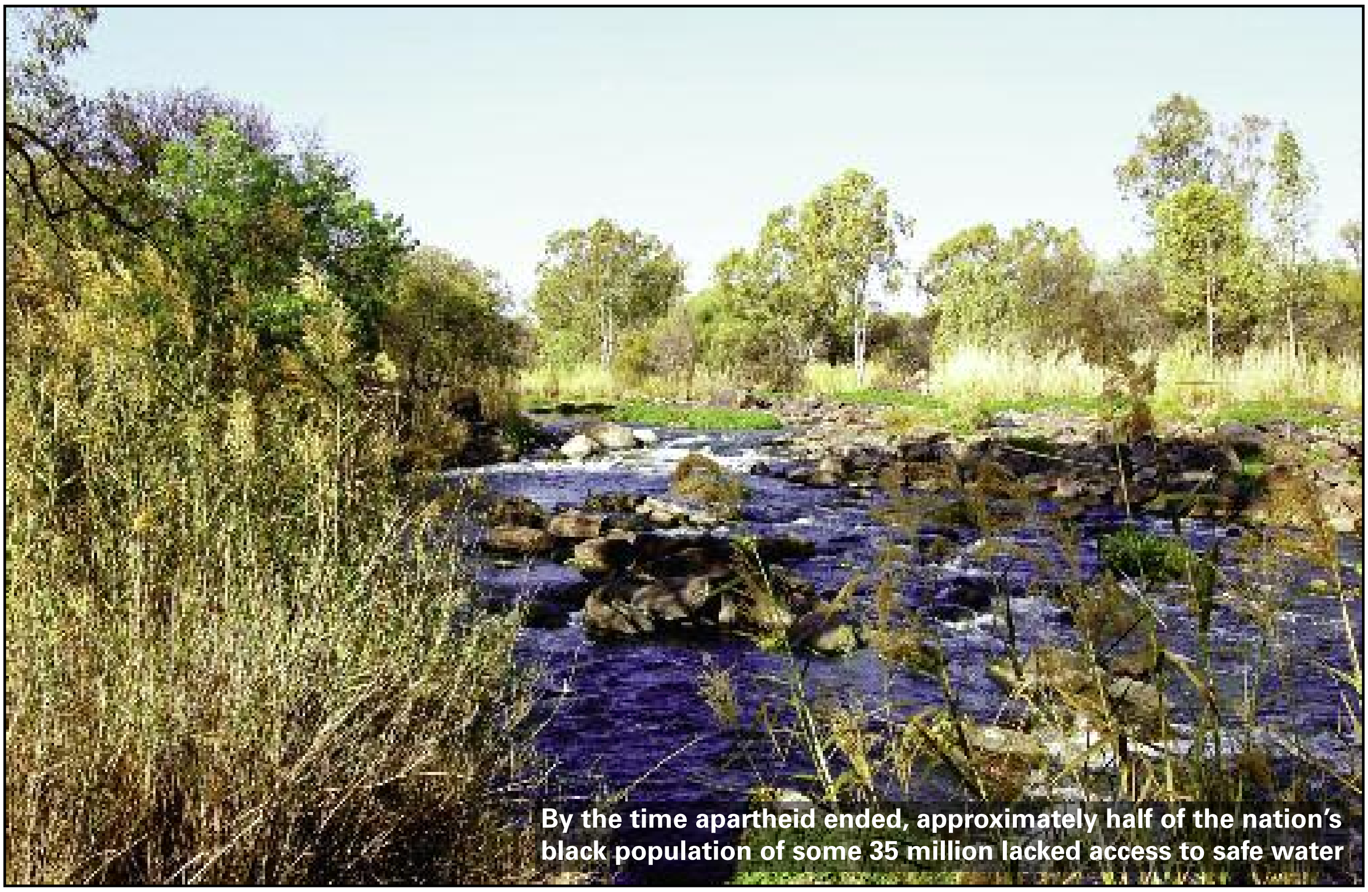
Since its inception, WfW has cleared more than one million hectares of invasive alien plants and provided jobs and training for around 70,000 people. Currently, it runs over 300 projects in all nine of South Africa's provinces, with about 25,000 people working under WfW at present with another 5,000 in the KZN IASP.

Realisation of benefits

However socially-oriented WfW may be, it is far from altruistic. Various analyses of the mechanics and magnitude of water savings within South African catchments demonstrate that total incremental water use by invasive plants, controlled by the Working for Water initiative, account for a significant amount otherwise ‘lost’ to MAR. Other studies to improve the targeting of removal of problem species in the most impacted places provide preliminary assessments of the costs, benefits and progress of WfW, demonstrating a considerable set of benefits associated with improved water yields (Le Maitre *et al*, 2004; Marais *et al*, 2004) and additional benefits for further ecosystem services (van Wilgen *et al*, 2007).

Beyond water quality and water quantity improvements consequent from increased yield of water from catchments, WfW delivers numerous additional benefits including biodiversity, job creation, on-the-job training in mechanical, chemical, biological and integrated methods of control, and contributions to the ongoing fight against poverty. Investments are also made in the development of communities where catchment control takes place. The social development focus of the work has also led to policies that ensure that the WfW programme reaches the ‘poorest of the poor’ including those living in rural areas and in Government-defined ‘poverty nodes’, women, youth, the disabled, single-headed households, those living with HIV/AIDS and/or fostering orphans, ex-offenders, ex-combatants and other such marginalised groups. Social justice and biological conservation must go hand in hand if they are to flourish in the long term.

Like many schemes around the world that also focus on restoration of ecosystems to recover critical ecosystem functioning, WfW demonstrates significant rates of return on investment in terms of economic and social benefits. Pertinent examples include the famous Delaware-Catskills water supply scheme in New York State, the SCaMP programme in the North-West of England (both reviewed by Everard, in press), and Paying for Ecosystem Services ini-


By the time apartheid ended, approximately half of the nation's black population of some 35 million lacked access to safe water

tiatives in the Maloti-Drakensberg in South Africa (Maloti Drakensberg Transfrontier Project, 2007) and the catchment of Kenya's Lake Naivasha. Like them, it also represents a preferable and sustainable alternative to heavy engineering solutions that seek to remedy symptoms rather than causes, and which are generally implemented only after damage has been done.

Success breeds success

The success of the Working for Water programme means not only that the scheme has continued since 1995 and been honoured by numerous national and international awards, but that it has spawned related initiatives across South Africa. There are three such closely-allied employment and catchment protection measures, targeting appropriate restoration initiatives for an identified set of environmental benefits that in turn yield societal benefits.

Working for Woodlands restores forestry functions benefiting catchment hydrology, biodiversity, characteristic landscapes and supply of sustainable fuel wood. Working on Fire is another EPWP programme dealing firstly with the prevention of wild fires, and secondly – although sadly a dominant feature – with the control of wild fires. There are of course benefits from Working on Fire for the control of invasive species and for catchment management including catchment hydrology. Thirdly, Working for Wetlands restores wetland habitats with their many critical ecosystem services including water storage and exchange with groundwater, buffering of flows including flood control (an increasing problem under climate change), recruitment of fish and other wildlife, nutrient and air quality regulation, and the maintenance of characteristic landscapes supporting traditional livelihoods, tourism and recreation potential.

All of these initiatives acknowledge uncertainties in the trajectory of ecosystem recovery following restoration management, making important the application of adaptive management strategies. Nevertheless, by placing the functioning of ecosystems at their heart, these programmes collectively deliver more sustainable results both ecologically and in terms of employment creation and improved support of livelihoods dependent upon the many services provided by ecosystems.

Principles extended around the world

The demonstrable success of the Working for Water programme is seen as an exemplar of integrated management of ecosystems for social, economic and environmental benefit. The principles embodied have been replicated around the world.

Some commentators suggest that the Working for Water model was influential in the decision by former US

President Clinton to initiate the Comprehensive Everglades Restoration Program (*www.evergladesplan.org*), one of the largest natural capital restoration projects in the world. By restoring degraded swampland, the Comprehensive Everglades Restoration Program helps overcome water quality problems resulting in greater availability of higher-quality water due to natural purification, boosts biodiversity including a number of vulnerable species, adds value to the tourism industry, restores natural floodwater controls, and serves a range of other associated benefits.

> ‘Arid landscapes amplify the importance of the inexorable linkage between the environment, the economy and social justice’

Related initiatives, not attributed to learning from Working for Water but nonetheless embodying some of the core principles of sustainable management of catchments for water yield and pollution control, include the Australian Landcare scheme (*www.landcareaustralia.com.au*), the Delaware-Catskills water supply scheme and local projects set up by the UK's network of voluntary River Trusts (as reviewed by Everard, 2004). SCaMP, addressed elsewhere in this journal, is another such well-regarded example. All further demonstrate the effectiveness of initiatives placing the functioning of catchment ecosystems at the centre of planning to improve hydrology, water quality and other ecosystem functions that produce the beneficial services enjoyed by catchment communities.

The ecosystems revolution

The Working for Water programme is a flagship for South Africa, linking social and environmental aspirations within one practical, demonstrably beneficial, economically advantageous and inherently sustainable scheme. It is also an exemplar of a growing body of initiatives across South Africa and the wider world, demonstrating the value of linking ecosystem functioning with the services, uses, values and societal implications of different options for development. Through the many direct and indirect social and economic benefits of restoration and management of catchments to enhance run-off of water, the ground is laid for sustainable progress giving local and often disenfranchised people a role and a stake in the 'market' for improved yields of water.

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THE SOCIO-ECONOMICS OF RIVER MANAGEMENT

When traditional uses of natural resources conflict with a booming human population, how can we find a route to sustainable development? **MYLES MANDER** and **MARK EVERARD** examine some of the tools that can be used to address the dilemma

Aside from supporting diverse life forms, ecosystem services produced throughout river catchments support a diversity of human livelihoods. They sustain basic life support needs such as drinking and cooking, irrigation of crop and grazing lands and stock watering, materials for shelter and energy, fisheries, as well as providing a raw resource for industry, a convenient waste receptacle and other economic benefits – not to mention supporting cultural and spiritual dimensions of human wellbeing.

Water is inseparable from human need, and all of its associated utilities can be ascribed economic values. However, a problem arises where there is no recognised market for these values, be they ecosystem services underpinning primary economic activities (such as water production in sparsely-populated uplands supporting industry, land use and habitation lower down the river system) or where they relate to human activities outside the formal economy such as traditional and subsistence lifestyles. Where these values are not reflected in management decisions, development options maximising short-term and localised financial returns will tend to erode the public goods generated by ecosystems to the detriment of catchment integrity, functioning and the many other sectors of society ultimately dependent upon it.

This article addresses three initiatives undertaken recently to help redress this shortfall across South Africa's arid landscape based upon its most fundamental resource: water and its multiple associated services.

Durban city planning

It has been traditional in city planning to consider limiting factors to economic growth including industrial capacity and inward investment, housing, amenity areas, yet all too often to overlook more fundamental resources that might ultimately constrain the value of urban expansion. The services provided by river systems serving these cities fall into this latter category, in terms not only of provision of water in adequate quantity and quality but also the capacity of river corridors to regulate flooding, provide amenity, dilute waste, produce food and other services besides.

The municipality of eThekwini, in which the city of Durban sits on the coast of KwaZulu-Natal in South Africa, recognised that over-use of river corridors converging on the city of Durban was indeed potentially limiting through impacts on the various ecosystem services they provide. From this realisation, eThekwini commissioned a study by the Institute of Natural Resources to explore the ecosystem services provided by these rivers. The resulting study (Diederichs *et al*, 2002) went well beyond that, presenting this information as a set of 'traffic lights' for each of the major tributary rivers in the form of an innovative planning guide with direct applicability to planning decisions.

The red/orange/green traffic light coding used in eThekwini Catchments: A Strategic Tool for Management represent the state of a range of ecosystem services – air quality, water quality, water quantity, flood risk, sedimentation/erosion, loss of biodiversity, agricultural production, and recreational/cultural/educational uses – for each of the tributary rivers serving Durban. For example, if a development proposal with a large impermeable surface is permitted in a sub-catchment that is already 'red' with respect to flood risk, the developer is graphically presented with the knowledge that exceeding this aspect of ecosystem carrying capacity can only hike flood risk elsewhere in the city.

The ecosystem service-based tool therefore provides a transparent basis for decisions founded upon limiting but often overlooked factors, supporting inherently more sustainable and equitable decisions and providing an evidence base to present to development proponents. The planning guide has been used since publication, and has been instrumental in informing a wide range of decisions, both routine and controversial. It also provides development proponents with an indicator of the likely obstacles they will encounter, from the perspectives of both planning authorisations and infrastructure design.

Options for the Tugela River

The Thukela Water Project: Reserve Determination Module. Part 1. IFR scenarios in the Thukela River Catchment: Economic impacts on ecosystem services, published by South Africa's Institute of Natural Resources (Mander, 2003), remains one of the most advanced studies of the broader consequences of different development scenarios across a major river system. The Thukela Water Project study explored the potential economic impacts arising from changes to the supply of a range of ecosystem services under different environmental flow options in the Thukela (Tugela) river catchment in the province of KwaZulu-Natal.

The Thukela Water Project deployed a variety of methods to ascribe economic values to the use of a range of ecosystem services by different communities in the river's major sub-catchments, then analysing how these would be affected by Instream Flow Requirement (IFR) impacts brought about by different damming and water management scenarios being considered for the Thukela. A comparison of status quo and affected conditions provided marginal benefits and costs associated with each possible flow regime, summarised finally as colour-coded 'traffic lights' for the selected range of ecosystem services across each of the major sub-catchments.

The economic value of the status quo condition was deduced by interviews with representative households throughout diverse rural and urban communities scattered across the major sub-catchments of the Thukela river system. Total economic value was calculated by multiplying the household benefit or disbenefit by the number of households enjoying the ecosystem service within sub-catchments. This provided a baseline for determining the marginal implications of different options for management of the river system. These were based on dependence upon a range of ecosystem services provided by the river system including fish (other than recreational fishing), reeds, sedges, waste assimilation, waste dilution, cultivated floodplain agricultural land, livestock grazing, whitewater rafting and kayaking, canoeing, recreational swimming, recreational fishing (trout) and recreational fishing (estuary). Ecological disservices were also addressed including Bilharzia (treatment costs), Bilharzia (loss of productivity), pathogens (treatment costs of diarrhoea), pathogens (loss of productivity through diarrhoea), pathogens (treatments costs of cholera) and pathogens (loss of productivity through cholera).

Some of these often-overlooked dis-benefits can be significant when economic value is factored into total outcomes. For example, the spread of waterborne diseases such as schistomsomiasis (Bilharzia) and diarrhoeal diseases may be accelerated not only by creation of large bodies of standing water behind dams but also through reduced dilution effects and declining flows lower in the catchment that favour the spread of invertebrate vectors (a mollusc in the case of schistomsomiasis) that transmit certain diseases. The Thukela Water Project provides evidence of potentially significant boosts in the incidence of Bilharzia and its associated economic impacts throughout the Thukela system under a range of dam development and water transfer scenarios. This mirrors the unanticipated yet widely-observed and often devastating spread of malaria and West Nile Fever across India consequent from dam construction.

For both the status quo and different environmental flow scenarios, data were incomplete and based on various assumptions. Total economic values deduced therefore had no absolute meaning. However, comparison of status quo and scenario values based on the same techniques and assumptions served the purpose of deriving marginal valuations illustrating directions of change, and their likely orders of magnitude, to ecosystem services and consequences (both beneficial or prejudicial) upon different dependent communities. These impacts included 'out-of-river' implications (changes to the volumes of water available for abstraction and direct economic use) and 'in-river' services (the implications of changes to the level of services supplied by the volume of water that remains within the river).

Analysis of marginal economic changes were compared to the status quo assessment by multiplying the scenario impact (i.e. 10% reduction to fishery potential) by the assessment of current economic value, also taking account of the population of beneficiaries. This was determined for eight tributaries, with four scenarios (including the status quo as a base reference) using 17 potential services (or disservices) that may change, with overall economic assessments as well as breakdown by service in each tributary: some 544 different conditions in all. To ease interpretation, numerical outcomes were also presented on a colour-coded basis: pale blue (no problem); green (good); orange (caution); and red (bad).

For many scenarios, a different balance of benefits was encountered in different sub-catchments across the river system, demonstrating the hazards of too broad a generalisation of impacts. Under some scenarios, disease implications were found to be particularly significant. Commonly, there was a significant redistribution of benefits and disbenefits across different groups of people whose livelihoods depend upon ecosystem services within the river system with some 'development' options likely to result in significant disadvantages for some sectors of society and occasionally all people in sub-catchments.

Significant changes in services were most often attributed to reduction of water volume with associated habitat loss, possible saltwater intrusion in lower reaches of a river consequent from reduced flows, loss of reeds and sedges (or in some flow scenarios significant increases) with consequences for indigenous construction and crafts, impacts on the capacity of rivers to dilute and assimilate wastes, lowering of the water tables on the floodplain, impacted floodplain grazing, affected recreation and fishing opportunities and, often with highly significant impacts, increasing habitat available to vectors or direct transmission of debilitating waterborne diseases including Bilharzia and cholera.

The INR study did not explore all ecosystem services as set out by the Millennium Ecosystem Assessment, although it did select a set that was representative and appropriate to the sub-catchments of interest. The evaluation was also based upon changes in environmental flows and not broader ecosystem processes (sediment trapping, changing water use habits, increased evapotranspiration,

The Drakensberg: exploring the links between 'production' upstream and consumption down-river

etc) which may further influence total marginal costs. However, the INR study provides a robust and graphic demonstration of the interdependence of ecosystem services and the way that they can impact different sub-catchments and sectors of society differently under different river management scenarios.

Above all, the Thukela Water Project summarises its complex analysis simply for decision-makers in central and provincial government through a 'traffic light' colour coding of net positive, neutral and negative impacts for the suite of ecosystem services across different sub-catchments, such that no decision can be made without commensurate exposure of its consequences for different communities. We would do well to learn from this approach, surely a pioneer of the kind of integrated assessment necessary to inform strategic decisions in the future, and to apply it more widely not only throughout Africa but across the globe.

Creating a market for the Drakensberg's water

The above measures address the protection or enhancement of the underpinning biodiversity that 'produces' ecosystem services, constituting a primary resource essential for cities, businesses and other users of water and its associated services. However, they largely do so without creating a market linking the 'producers' and 'consumers' of these services. There are, however, emerging initiatives around the world that implement a Paying for Ecosystem Services (PES) approach founded on creation of markets.

South Africa's innovative water laws, which enshrine the principles of equity, sustainability and efficiency, have enabled the development of some of the most advanced approaches to PES in the world. The Maloti Drakensberg Transfrontier Project, published in 2007, explored hydrological and economic linkages between uplands that 'produce' water and the consumption of water lower down in selected river catchments, progressing this into the design of market mechanisms for payment from consumers for the protection, restoration and management of upper catchment areas critical for dependable run-off of clean water. This market is founded upon the economic benefits to communities lower down catchments, particularly focused on heavy water users such as forestry, intensive agriculture such as sugar production, mining and industries such as paper mills, which may benefit from investing in work to increase the water yield of the catchments upon which they depend. This market model is finding favour with the South African government as a market means to embed the ecosystems approach as a basis for the equitable, sustainable and efficient provision of water. A legal review by Quibell and Stein (2005) concludes that payment mechanisms can provide a basis for the equitable and sustainable management of South African catchments.

Other PES initiatives are finding favour around the world, including in South Africa where the Maloti Drakensberg study builds upon Working for Water and related Working for Wetlands, Working on Fire and Working for

Woodlands initiatives. Elsewhere in Africa, PES techniques are being explored in the Lake Naivasha basin in Kenya. PES is also implicitly the intent of the UK's Environmental Stewardship and the EU CAP agri-environment regime to maximise public benefits from land management, and novel approaches to flood risk management that step back from merely defending drained land at any cost and instead seek an optimal balance of ecological, social and economic benefits in novel flood risk schemes that may as readily entail rewetting of formerly defended land as a means to store flood peaks. The famous story of New York City's public water supply may be the largest such market in the world, with water service charges to city consumers reinvested in appropriate land management in the up-state rural catchments from which fresh water is drawn. SCaMP too, also addressed in this journal, is an example of PES in action with payment through water service charges reinvested into land restoration and management agreements in vulnerable and productive uplands all under the aegis of agreements sanctioned by the UK government under statutory Asset Management Planning agreements.

‘Water is inseparable from human need, and all of its associated utilities can be ascribed economic values’

In terms of more accurate reflection of the value of ecosystem services within our market economy, PES offers great hope for a more sustainable relationship with biodiversity but also reflecting the dependence of communities upon the ecosystem services that it provides and the importance of these services for equitable access to resources. PES also offers participating businesses a basis for securing the core resources upon which their stability and progress depends. Furthermore, the ‘subsidised farmers’ conundrum, an issue of growing political unease around the world, can be addressed by shifting from subsidised agricultural goods to paying farmers via market-based mechanisms for the ecosystem services they supply to society; by paying farmers for the delivery of specific ecosystem services, we can move decisively away from vague and globally unsustainable subsidies towards the reward of identifiable public goods.

Conclusions

We live in challenging times, when the consequences of established natural resource use habits is conflicting with booming human populations. We have to find another pathway of development that respects the fundamental importance of critical natural resources. Water is one such critical natural resource, vital to the wellbeing and potential of all and particularly in water-stressed countries such as South Africa where the added stress of climate change exacerbates risks.

The re-engineering of society in South Africa in the post-apartheid era creates opportunities for novel approaches to the management and sharing of natural resources that address, as stated in the National Water Act 1998, simultaneous fulfilment of the principles of equity, sustainability and efficiency. The three mechanisms discussed above are practical tools for this re-engineering process, helping to re-imagine established water use patterns and providing feasible alternative use paradigms with greater built-in sustainability feedbacks.

Greater sustainability may realistically take a generation to achieve. However, realising this goal depends not only upon respecting and accommodating human diversity but also the biodiversity that supports the livelihoods and resilience of all people sharing catchments. It is through the kinds of innovative planning, development support and market mechanisms highlighted in this article that society can progressively re-imagine the role of the water cycle in society, and provide the necessary incentives for appropriate management of fundamental societal cornerstones such as clean and abundant water.

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ECOSYSTEMS, WATER AND OUR COMMON FUTURES

Instead of feeling guilty about past mistakes, we must look forward and see how new knowledge can inform sustainable management principles, suggests **ANDREW BARRETT-MOLD**

Our planet is set to undergo changes on a scale hitherto unseen by humans. A growing human population – and growing affluence – will place more demands than ever before on the ecosystems that support it.

As global population grows, demand for fresh water resources from lakes, rivers and aquifers increases, affecting the flow dynamics of rivers and streams and creating impedances such as dams. These effects significantly alter biodiversity, often to the detriment of ecosystem structure, integrity and functioning although sometimes to enhance certain benefits. For example, changes in biodiversity due to human controls on the ecosystem can be seen in the establishment of inland fisheries. These may represent the main source of animal protein for some people, particularly in countries in South-East Asia where other forms of protein are less available. In these cases, the commercial farming of particular species leads to a decrease in diversity of the waterway as whole; benefits to a local human community must be weighed against costs to ecosystems, both locally and in terms of their impact on broader ecosystems and the people dependent upon them.

Rapid development in certain regions is giving a larger proportion of the global population access to the affluence already enjoyed across the developed (or western) world. With this comes a shift in habits and diets, such as greater demand for protein-rich foods, which in turn demands greater irrigation for the additional crops required to feed livestock. The implications of this shift can already be seen in the shape of rising grain prices, differentially affecting the poorest countries, and greater competition over the use of grain for livestock, human consumption and the increasing application of biofuels.

Where surface runoff isn't available to supply drinking water, communities often depend upon groundwater. The Millennium Ecosystem Assessment (MA) estimates that groundwater supplies between 1.5 and 3 billion people with drinking water globally. Groundwater may be recharged from wetlands, but in some cases it is non-renewable. This 'fossil' water, such as that which currently supports three-quarters of the supply in Saudi Arabia (Vitousek, 1997), will inevitably be depleted with long-term consequences for the security and viability of ecosystems and people. The MA estimates a global renewable water resource of between 33,500 and 47,000 cubic kilometres per year in terms of mean runoff (MA, 2005). Changes in precipitation patterns and increased rainfall associated with climate change are likely to generate negative effects that outweigh any positive effects (IPCC, 2007). Human demand for this water is large and increasing, feeding the likelihood of conflict between different users at all scales. Therefore, the capture, storage and purification of water, as well as its use, will need to become increasingly efficient. Ecosystem functions play a key role in these processes, positioning effective ecosystem management as a priority in the planning and management of water resources.

Editor's note: Contributions to this special edition are those of established scientists around the world. However, respecting our student members and also the voice of emerging generations, we decided to invite a contribution from the student membership of the IES.

> 'A growing human population – and growing affluence – will place more demands than ever before on the ecosystems that support it'

The conservation of ecosystems and their biodiversity range from local to global measures; international cooperation is required to implement them. Threats to ecosystem integrity and functioning have an international dimension, but so too do the benefits of ecosystem conservation. The European Community has set a plan to halt all loss of biodiversity by 2010 (the 'Gothenburg target') through various directives that protect sites supporting vulnerable species and land habitats, and also by integrating nature conservation measures into all other 'Community' policies such as the Common Agricultural Policy (CAP). However, it has become apparent that the 2010 target will not be reached, despite a significant change in the CAP policy focus towards conservation, largely for financial reasons. Prevention of biodiversity loss, even beyond 2010, will require European member states to accept their obligation to enforce legislation (Jack, 2006).

Within international law, there are three principles that relate directly to conservation of ecosystems: the precautionary principle; the principle of intergenerational equity; and the principle of differentiated responsibility. The precautionary principle is often applied whenever science is equivocal, erring on the side of caution in decision making (for example where the risks associated with commercialising a new technology are not adequately characterised). The idea of intergenerational equity was generally agreed upon during the Rio de Janeiro Earth Summit in 1992, indicating that future generations share the same rights of access to ecosystems as current generations. The principle of differentiated responsibility indicates that countries with the resources to conserve diversity (i.e. the developed or western world) have a responsibility to act as a spear-head for any action taken.

Globally, a substantial proportion of biodiversity is found in relatively poor countries in the southern hemisphere. If the international community wishes to prevent the loss of this biodiversity, incentives must be made available to encourage its conservation. A large amount of international law currently relates to biodiversity, most notably stemming from the Earth Summit. However, this needs further development and currently involves inconsistencies that need to be corrected, particularly by re-examining the intellectual property rights of countries to the informational value of biodiversity (Bodansky, 1995).

> Substantial progress remains to be made in the revision of our perceived role, not only in the management of ecosystems but in our relationship with them

The increasing rate of development, particularly of countries with large populations, is often viewed with concern by observers in the developed world. It is essential to respect the right of all people to develop, noting the lessons of unsustainable pathways of development that we have exemplified. If we are to expect others to include sustainable measures to conserve the biodiversity of the ecosystems, the already-developed (western) world has an obligation to assist in terms of fair trade and appropriate cleaner technology transfer.

In this regard, the MA has proven extremely helpful by highlighting the many benefits that are provided to society by ecosystems, bypassing inherent difficulties in the valuation of habitat or species for their own intrinsic sake. Since water is a critical and often limiting resource around the globe, the availability of which is likely to become increasingly constrained by environmental change and human population growth, the evolution of the law and the application of sustainability principles becomes ever more urgent.

Notoriously, conservation initiatives have a history of limited resources. The introduction of ecosystem services as a justification for the protection of biodiversity is not only timely but also relevant, as it is intact and functional ecosystems that produce many of the benefits enjoyed by society, albeit that the relationship between the two is complex and as yet poorly understood. Recently there has been increasing interest in mapping the ecosystem services of particular regions in order to allocate resources most efficiently for maximum return. If the benefits of conservation can be accurately demonstrated through the ecosystem services approach, this is likely not only to advance the cause and resources available for conservation, but also to help humanity address its pressing global responsibilities.

Crucially, we need to redress our historic world view of humanity sitting at the top of an ecological chain, free to reap the benefits yielded by levels below it without long-term consequence. Whilst it remains true that we do indeed depend upon these ecosystem-generated resources, we need to replace our self-perception with a more realistic model wherein we humans exist as one of a multitude of nodes within a complex web of fully interdependent, co-evolved life forms. This world view certainly challenges many of the implicit assumptions of our industrial past.

Only relatively recently has humanity become more aware of its responsibilities to the conservation of ecosystems. Substantial progress remains to be made in the revision of our perceived role, not only in the management of ecosystems but in our relationship with them. This is a call not to feel guilty for our historic pathway, embarked upon with the best of intentions, but rather to look forward to how environmental science and other new knowledge can further inform sustainable management principles. Although the challenges remain daunting, the process of change is not difficult to achieve if we take due consideration and commit ourselves to increasing our understanding and continual learning.

◆ Andrew Barrett-Mold has just come to the end of a four-year M.Ocean degree at Southampton University, and has become interested in palaeo-studies and geochemistry. Andrew would like to move into science journalism but is also attracted to research.

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