Article (refereed) - postprint

Hails, Rosemary S.; Ormerod, Steve J. 2013. **Ecological science for ecosystem services and the stewardship of Natural Capital**. *Journal of Applied Ecology*, 50 (4). 807-810. 10.1111/1365-2664.12127

Ecological science for ecosystem services and the stewardship of Natural Capital

EDITORIAL

Hails, R.S.[*1] and Ormerod, S.J.[2]

1. *Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxon. OX10 8BB, UK.*
2. *Cardiff School of Biosciences, Cardiff University, Cardiff, CF10 3AX, UK.*

Summary

1 National and international assessments are increasingly highlighting the unsustainable use of earth's natural resources in the face of population increase, growing material affluence and global change. In all likelihood, the use and degradation of natural resources will continue.

2 In contrast to resource depletion, the concept of natural capital emphasises how the environment is an asset to be managed, to ensure that the benefits which flow from it are sustained for future generations. These benefits are the ecosystem goods and services upon which all people rely for their continued survival and well-being both now and, ideally, in perpetuity.

3 Despite their importance, the evidence-base and quantitative understanding of links between biodiversity, ecosystem function and ecosystem services are insufficient to allow informed use and management. Moreover, the concepts of natural capital and ecosystem services are insufficiently mainstream to influence decisions that currently favour the production of food and fibre rather than less tangible services such as climate regulation, air and water purification, pollination or the contributions of environment to health.

4. There are specific challenges to ecological science in this interdisciplinary endeavour: specifically, to develop frameworks for identifying and monitoring natural capital; to parameterise factors affecting ecosystem services and their resilience to change; to integrate the complexity of ecological systems into ecosystem service valuation; and to characterise the synergies and trade-offs between ecosystem services in different management and policy scenarios.

5. *Synthesis and applications.* The five papers in this Special Profile exemplify just some of the leading work through which ecologists in the UK are contributing nationally and internationally to these needs. Stemming from the UK National Ecosystem Assessment – the first national scale exercise of its type in the world. We expect a major, worldwide increase in work on ecosystem services and natural capital in future as decisions on ecosystem use of management are squeezed increasingly between the needs of exploitation and protection.

[*] Corresponding author rha@ceh.ac.uk

Introduction

Without the earth's biological diversity, our lives would, literally, be nothing. In both the natural and built environment, biological diversity underpins ecosystems, which in turn support all the activities on which we depend for health, wellbeing, prosperity and inspiration. The Millennium Ecosystem Assessment (MA) was the first formal international synthesis that explicitly linked human well-being and ecosystems, of which people were seen as a key part, driving ecosystem change and in turn being affected by the consequences (MA 2005). The MA summarised the direction of travel over the last 50 years: that humans have exploited and changed ecosystems more rapidly over this period than any other; that this exploitation has contributed to substantial net gains in human wellbeing; but that these gains have been made partly at the expense of the 'natural capital' at the foundations of our life support systems. The living elements of natural capital are the stock of ecosystems from which flow a range of benefits – in other words ecosystem goods and services – which improve human health and wellbeing; if properly managed, these benefits could be sustained for future generations. However, the MA concluded that 60% of ecosystem services were being degraded or used unsustainably. There are potential solutions, but this will require very significant changes in the way in which we manage natural capital.

These are very significant issues that must be addressed if we are to anticipate and manage the problems arising from our continued exploitation of natural capital. Most pertinent to this Journal, they are problems that sit at the core of applied ecology, and encapsulate an important contribution that ecologists should make in partnership with the physical and social sciences.

The MA formed the basis of the UK National Ecosystem Assessment (UKNEA) which reported in June 2011 – amongst the first national-scale assessments of ecosystem status and ecosystem services anywhere in the world (see http://biodiversity.europa.eu/ecosystem-assessments/assessments). This first comprehensive review of ecosystems in the UK's natural and built environment broke new ground in envisioning scenarios and drivers of future ecosystem change. Building on the conceptual framework of the MA, the UKNEA took the first steps in developing more effective tools to translate knowledge on trends in ecosystem services into action for policy and management at all scales from the local to the global. Key conclusions were that i) ecosystem management has emphasised resource production, for example for food and other provisioning services, often disproportionately and to the detriment of less tangible services; ii) some critical ecosystem services are declining, yet there is only rudimentary understanding of how diverse organism functions sustain them; and iii) pressures on ecosystems will intensify because of future resource demands and changing climate. Interdisciplinary collaboration with economists and social scientists also developed new methods to value ecosystem services in economic, health and social terms. Valuation focused on the final services, avoiding double counting the contribution of intermediate and supporting services, and teased apart the contribution of natural capital from human and manufactured capital in the production of goods. It was also recognised that non-monetary values (such as shared social values) need to be considered alongside more easily quantified economic values, although challenges remain as to how to best achieve this (Mace and Bateman 2011).

Many other nations, states and regions are now developing their own ecosystem assessments. For example, in Europe, similar exercises have been completed in Portugal and Spain, and are ongoing in Switzerland, Germany and Norway, while twelve other countries are undertaking scoping exercises.

In India, ecosystem assessments are already either completed or ongoing in several states. This approach has also gained momentum internationally, with the establishment of the Inter-Governmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, see www.ipbes.net) , which is designed to play an analogous role to the Intergovernmental Panel on Climate Change (IPCC) in the area of biodiversity, ecosystem services and human well-being.

Building on National Ecosystem Assessments

In the UK, the NEA had rapid and major influence on local and national policy as presented in subsequent 'white papers' – documents used by government to present policy to a wide audience. Its ideas ran throughout the Natural Environment White Paper 'The Natural Choice' (NEWP 2011) and the Water White Paper (Water for Life 2011). It was core to Defra's Biodiversity Strategy for England (Biodiversity 2020: A strategy for England's wildlife and ecosystem services), and pivotal in framing new national policy in Scotland (Getting the best from our land: A Land Use strategy for Scotland. www.scotland.gov.uk/Publications/2011/03/17091927/12) while also shaping Wales' new, integrated, nationwide body for regulation and the environment, 'Natural Resources Wales'.

The central thesis of the NEWP was to recognise more effectively the values and benefits that flow from the natural environment, and to incorporate these values into decision making. This was a significant change of paradigm: no longer should the environment be considered as a trade-off in which economic growth was gained only at the expense of environmental degradation. Instead, the term 'Natural Capital' emphasises how ecosystems and their component parts should be viewed as assets from which services and benefits are accrued. Natural capital is a term in common parlance of environmental economists, where it sits alongside the other four forms of capital (financial, manufactured, human and social), illustrating that it has value, that the quantity and quality of that capital should be maintained or this value will decline, and that measurement of that value will enable the full consequences of different actions to become apparent. Commitments of the NEWP include a) the establishment of the Natural Capital Committee to advise the government on the unsustainable use of Natural Capital, and the incorporation of Natural Capital into national accounts; b) the creation of Local Nature Partnerships and Nature Improvement Areas to facilitate the recovery of nature; and c) establishment of a Green Infrastructure partnership to support the development of green infrastructure in towns and cities. Since the publications of the NEWP in June 2011, these frameworks have been created and much is in place to deliver an ambitious agenda. There is now a major imperative for ecologists to contribute to the process.

Challenges for Ecological Science

One of the central themes of the NEA also has relevance beyond the UK, and applies to ecosystems and their services everywhere. Crucially, we need to develop our understanding of how biodiversity – genes, individuals, species and communities – interact to determine ecosystem function, and to deliver ecosystem services. Sustaining those same functions and services in the face of resource exploitation and global change are also among our major challenges as the earth's population grows, and as pressures bear down not only on soil, water, food and fibre production, but also on the less tangible needs to maintain biodiversity, maintain regulation of the Earth's climate, maintain the processes which purify water and enable decomposition and nutrient cycling. Without fuller knowledge of which organisms should be where and in what combination, of how biodiversity losses

or gains will influence ecosystem function, decisions around the management of natural capital will be taken in a knowledge vacuum.

Fundamentally, the diversity of living organisms underpins the functioning and resilience of all ecosystem services, providing the 'building block of habitats and ecosystems' (UKNEA 2011). Mace et al (2012) illustrated the three ways in which the diversity of organisms and ecosystems contribute to the ecosystem services framework: through underpinning processes or supporting services, through the delivery of 'diversity' as a final ecosystem service in its own right, and in the delivery of specific species and landscapes which hold great cultural significance for many, and which can be valued as 'goods'. There are concerns that biodiversity loss may compromise ecosystem service delivery in the future, yet the links between specific elements of biodiversity and the ecosystem services they deliver are often poorly understood or quantified. A review of those links revealed a cultural divide among biodiversity groups and associated ecosystem services (Norris et al 2011). On the one hand, our monitoring networks provide good information on the status and trends of many biodiversity groups of cultural significance (e.g. Roy et al 2012), yet we have little quantitative information on the linked cultural services, and would find it hard to predict how these would change with biodiversity loss. On the other hand, changes in provisioning services are often well quantified, but data on the underpinning biodiversity groups are poor. Defining such links is now the essence of a major UK research initiative (Biodiversity and Ecosystem Service Sustainability, www.nerc-bess.net) Scoping studies have also explored how the dynamics of ecosystems can be included in the valuation of Natural Capital (the Valuing Nature Network, www.valuing-nature.net). There is also a major initiative on how the management of ecosystems can reduce poverty and enhance the wellbeing of some of the world's poorest people (Ecosystem Services for Poverty Alleviation, www.espa.ac.uk). These UK based initiatives, all funded by the Natural Environment Research Council, build upon the legacy of a pioneering initiative from the United States, the Natural Capital Project (www.naturalcapitalproject.org). This initiative develops and demonstrates tools which enable natural capital to be incorporated into decision making; many of the UK projects are developing these tools in particular contexts. Other such initiatives are likely to develop globally.

Nevertheless, significant challenges remain. To meet the aspiration '*to leave the natural environment....in a better state than...inherited*' (NEWP 2011) will require an evidence-based strategy for the stewardship of Natural Capital. Many observation and monitoring systems for the natural environment were established before the ecosystem service framework became widely used, and are often highly specialised networks focusing on specific elements of biodiversity. In some cases, these data act as indicators for wider biodiversity, and have been shown to respond to changes in management in the countryside (e.g. Baker et al 2012). In general, however, the links between the metrics we currently monitor and either the underpinning Natural Capital or the final Ecosystem Services are not well defined. Measurement and monitoring using appropriate metrics is a first and necessary step towards Natural Capital stewardship.

A second challenge lies in how to ensure that the environment is properly valued when critical decisions about natural capital are made (e.g. land use, policy development). The specific ecological challenge in this context is to incorporate the complexity of ecological processes into valuations of ecosystem services. There are likely to be non-linear relationships between the stocks of natural capital and the benefits that flow from them, that will influence how those benefits are valued; yet these relationships remain uncharacterised. Valuing ecosystem services is controversial, seen by

some as a prelude to privatisation, by others as a necessary step to ensure that the environment is not given a default value of zero in many decision making processes. Better integration of the values that flow from the environment into decision making could fundamentally reshape policy around natural capital stewardship.

The third challenge lies in developing management strategies for Natural Capital that ensure sustainability of the ecosystem services we need for the future: in acting now and in the spirit of inter-generational equity, ecologists must have their eyes on the needs of the generations that follow ours. This will require an understanding of the synergies and trade-offs that exist in the delivery of ecosystem services. One of the best understood trade-offs is that between provisioning services and biodiversity: for example grassland may be improved for livestock by the addition of fertiliser, but this may mean lower diversity of wild flower species of cultural significance (Bullock et al 2011). Many synergies and trade-offs remain uncharacterised, and this limits the abilities of land managers and decision makers to implement measures that would deliver multiple benefits. Delivering multiple benefits requires, in turn, a truly inter-disciplinary endeavour that places that work of ecologists alongside a wide range of other fields.

Ecological science for ecosystem services and the stewardship of Natural Capital: contributions to this special profile

The papers collected here, science inspired by the UKNEA, illustrate some of the first steps along the road to determining how we can best manage the earth's natural capital to ensure we meet the ecosystem services needs of this and future generations. As is so often the case in the Journal of Applied Ecology's 'Special Profiles', the papers in this selection represent a diverse body of work at the cutting edge of our subject – in this case the scientific debate around the ecosystem services and natural capital themes.

In a review remarkable for its breadth as well as its grasp, Smith et al. (2012) crystallise an array of major regulating services that should be underpinned by fully-functioning ecosystems – crucially in maintaining the quality of air, water, soil and climate systems from which all other goods and services ultimately flow. On the one hand, the paper illustrates the interconnectedness of the pathways through which major ecosystem services are delivered, but on the other it illustrates examples where policy fails to capture this notion by focussing on single areas that do not take co-benefits or trade-offs into account. The authors postulate that more coherent management framework could arise from greater recognition of ecosystem processes even in the absence of a full valuation of all the contributing components.

Gaston et al. (2013) remind us that the built environment has particular prominence in ecosystem service science. This is not only because most of the beneficiaries now reside in urban areas, but also because the structures and ecosystem attributes of urban space simultaneously affect the ways that goods and services are produced while either constraining or vectoring flows from sources to users. In these locations, there are major opportunities to align planning, landscape ecology and ecosystem management more clearly to enhance the well-being of billions of people.

Jiang et al. (2013) illustrate the value of combining maps with unique long-term data to demonstrate how the balance between provisioning services for agriculture and biodiversity conservation has tipped against the latter over a 70-year period even in a European region where agriculture is not

particularly intense. In contrast, carbon storage has been maintained or enhanced by conifer planting – albeit with some conflicts and costs to the conservation of semi-natural habitat. This case study illustrates how historic data can be used to inform the land management decisions for the future. By developing an understanding of how past land use configurations have impacted on biodiversity and ecosystem service delivery, strategies for restoration can set achievable goals. This approach is globally applicable; such regional long-term analyses have the potential to add major insights into policy development, for example the ecosystem service aims of the EU biodiversity strategy (European Commission 2011).

Jones et al. (2013) take an explicitly ecosystem biogeochemical approach to ecosystem services, and specifically their role in agriculture. They evaluate the global balance between the use and loss of macro-nutrients (P and N) and the failure to maintain improvements in agricultural yield coupled with the impending problem of micronutrient depletion (Se, Cu, Zn). Yet again, work of major applied significance follows with advocacy for the need to re-engineer agriculture at all scales – but led by national initiatives - to safeguard nutrient stocks, limit removals and export, and enhance recycling. The alternative, of progressively depleting nutrient sources to support a diminishing base of agricultural production in an increasingly food-limited world, seems untenable.

Finally, in a view specifically from those involved in a sector involved directly with ecosystem services – that of multi-purpose forestry – Quine et al. (2013) offer a "practitioners perspective". Like others charged with delivering the ecosystem services paradigm in practice, they rehearse views on the strengths, weakness, opportunities and uncertainties of the approach. While drawing attention to value of the ecosystem services concept in attracting support for ecosystem protection from politicians and industrialists, they also articulate risks where management based on valuation might narrow focus onto explicitly marketable goods, diminish emphasis on resources that are hard to value, and work against the flexibility required for adaptive management to combat climate change. They recommend that: i) more attention be given to valuing multiple benefits; ii) mechanisms be sought for financing specific services within broader management objectives; iii) we bolster our understanding of how ecosystem functions are optimised in managed sectors such as forestry and iv) that ecologists probe the ecosystem services concept just as critically as they would any other emerging environmental governance model.

Conclusions

It is clear that our exploitation of the natural environment and the assets it contains is set to continue, to increase, and in some cases to be unsustainable. However, the information on which to manage our natural capital more effectively is often incomplete. Even the fundamental links between changes in biodiversity and the benefits produced by the environment are often poorly characterised, let alone the impact of changes in natural capital on our financial economy and our health and well being. We urgently need more coherent ecosystem management strategies for Natural Capital Stewardship. This is an interdisciplinary endeavour.

The scale and importance of the task means the papers collected here represent a significant point of departure for applied ecologists in general, and for this Journal specifically: we expect the focus on natural capital and ecosystem services to intensify in the years ahead as decisions on ecosystem management are squeezed increasingly between the needs of exploitation from a growing

population and protection to ensure its well-being. Ecologists must be prepared to look into a long future and imagine how the world will look if our efforts fail.

References

Baker, D.J., Freeman, S.N., Grice, P.V. and Siriwardena, G.M. (2012) Landscape scale responses of birds to agri-environment management: a test of the English Environmental Stewardship Scheme. *Journal of Applied Ecology*, 49, 4, 871-882.

Bullock, J.M., Jefferson, R.G., Blackstock, T.H., Pakeman, R.J., Emmett, B.A., Pywell, R.J., Grime, P., and Silvertown, J. (2011). Semi-natural Grasslands. Pp 161-195 *In*: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

European Commission (2011). Our life insurance, our natural capital: an EU biodiversity strategy to 2020.

Gaston, K., Avila-Jimenez, M. And Edmondson, J. (2013). Managing urban ecosystems for goods and services. *Journal of Applied Ecology*,

Jiang, M., Bullock, J., Hooftman, D. (2013). Mapping ecosystem service and biodiversity changes over 70 years in a rural English county. *Journal of Applied Ecology*,

Jones, D., Cross, P., Withers, P., DeLuca, T., Robinson, D., Quilliam, R., Harris, I., Chadwick, D. And Edwards-Jones, G. (2013). Nutrient stripping: the global disparity between food security and soil nutrient capital. *Journal of Applied Ecology*,

NEWP (2011). The Natural Choice: securing the value of nature. www.official-documents.gov.uk.

MA (Millennium Ecosystem Assessment) (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington D.C.

Mace, G.M. and Bateman, I. (2011). Conceptual Framework and Methodology. Pp 11-25 *In*: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Mace G.M., Norris, K. and Fitter, A.H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology and Evolution,* 27 (1), 19-26.

Norris, K. (and others) (2011). Biodiversity in the context of ecosystem services. Pp 63-104 *In*: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Roy, H.E., Pocock, M.J. Preston, C.D., Roy, D. B., Savage, J., Tweddle, J.C. & Robinson, L.D. (2012) Understanding Citizen Science & Environmental Monitoring. Final Report, UK-EOF.

Smith, P., Ashmore, M.R., Black, H.I.J., Burgess, P.J., Evans, C.D., Quine, T.A., Thomson, A.M., Hicks, K. and Orr, H.G. (2013). The role of ecosystems and their management in regulating climate, and soil, water and air quality. *Journal of Applied Ecology*,

Quine, C., Bailey, S. and Watts, K. (2013). Sustainable forest management in a time of ecosystem services frameworks: common ground and consequences. *Journal of Applied Ecology*,

UK NEA (2011). The UK National Ecosystem Assessment: Synthesis of Key Findings. UNEP-WCMC, Cambridge.

Water for Life (2011). www.official-documents.gov.uk