POLICY PERSPECTIVE

Ecosystem services and conservation strategy: beware the silver bullet

Bhaskar Vira & William M. Adams

Department of Geography, University of Cambridge, Cambridge CB2 3EN, UK

Keywords
Ecosystem services; biodiversity conservation; natural capital; trade-offs; ecosystem processes; stocks and flows.

Correspondence
Bhaskar Vira, Department of Geography, Downing Place, Cambridge CB2 3EN. Tel: +44 (0)1223 339823; fax: +44 (0)1223 333392.
E-mail: bv101@cam.ac.uk

Received: 23 March 2009; accepted 7 May 2009.

doi: 10.1111/j.1755-263X.2009.00063.x

Abstract

There is an important analytical distinction for conservationists between the flow of ecosystem services and the stock of natural capital that underpins or constitutes them. The relationship between these two is often complex and indeterminate. Ecosystem services result from the interplay of different biological and physical processes across a variety of scales. Flows of ecosystem services may be imperfectly related to stocks of natural capital. Conservation is concerned with the protection of certain stocks of natural capital, but also with maintaining the complex web of relationships that characterize biodiversity. Despite the obvious links between ecosystem services, natural capital, and biodiversity, these are not identical. Practitioners and policy makers should be cautious in their use of the proxy indicator of ecosystem services when developing mechanisms for biodiversity conservation. Conceptual clarity is essential in order to harness the potentially important role that ecosystem service based interventions can play in mainstreaming conservation issues.

Conservation and ecosystem services

Debates at both the Fourth World Conservation Congress in Barcelona in October 2008 and the Conference of the Parties to the United Nations Framework Convention on Climate Change in Poznan in December 2008 confirmed the importance of ecosystem services to current debates about biodiversity conservation (Daily *et al.* 2000, 2009; Armsworth *et al.* 2007) and in expressing the dependence of human well-being on natural capital (Turner & Daily 2008). Payments for ecosystem services (Wunder 2006), particularly carbon sequestration in forests, promise "win–win" outcomes that deliver benefits for biodiversity, poor people, and climate (Miles & Kapos 2008).

We suggest that there is a risk that valuation and trading of ecosystem services will be seen simplistically by conservation practitioners as a "silver bullet," offering a simple and effective solution to complex and intractable resource management problems (Landell-Mills & Porras 2002). The danger is that hasty and uncritical adopters of new paradigms overload them with hope, leading to disillusionment and premature abandonment (Adams & Hulme 2001). Caution has been urged about the potential impacts of ecosystem service markets on the poor (Landell-Mills & Porras 2002), and the utilitarian valuation of biodiversity that underpins ecosystem service analysis (McCauley 2006; Reid *et al*. 2006). While we recognize the contribution that economic analysis based on an ecosystem services framework can make to mainstreaming the conservation of biodiversity, we also advocate the need for conceptual clarity while adopting economic paradigms for conservation. The ecosystem services approach may provide a useful additional argument for conservation, but practitioners should be cautious about the potential pitfalls of utilizing economic metaphors that are not always perfectly related to the biological systems that are the subject of conservation interest.

In this article, we draw attention to some specific reasons for caution, by focusing on the complex relationship between stocks of renewable natural capital and flows of ecosystem services in the form of materials, energy, and information derived from these stocks (Blignaut & Aronson 2008). While natural capital is a useful economic concept, it does not capture the full complexity of relations between genes, species, and ecosystems that is associated with the term biodiversity (Wilson 1992). Moreover, the processes by which stocks of natural capital are transformed into flows of ecosystem services are themselves not straightforward. In this article, we discuss three specific problems: (1) the role of intervening factors that affect the delivery of ecosystem services from stocks of natural capital; (2) the significance of type of service for the stock-flow relationship; (3) and the relationship between scarcity, human demands, and market values, which can create perverse outcomes for conservation.

Intervening factors affect the delivery of ecosystem services

First, various factors affect the capacity of stocks of biological natural capital to supply ecosystem services. The biodiversity/service production function is determined by the complex interplay of biological and physical processes across a variety of scales. Thus, forest catchment water yields depend directly on ecological patterns (e.g., vegetation cover, canopy architecture, and rooting patterns), but also indirectly on geomorphological, geological, hydrogeomorphic, and biogeochemical processes (Bruijnzeel 2004; Aylward 2005; Sidle *et al.* 2006). If change in these factors (e.g., pollution, dam construction, channelization) affects the value of water to downstream users, the conservation case for forest preservation is undermined, without any change in the characteristics of the forest itself. The provision of water services from an upstream forested catchment might support the case for conservation of the natural capital in the biodiversity of the forest, but only if these services are actually delivered to the downstream end user. Similarly, the extent to which flood control services are provided by a riverine wetland will depend on the physical structure and floristics of terrestrial vegetation, and in turn on the structure and functioning of linked aquatic and terrestrial ecosystems, themselves affected by the physical form and sedimentology of the floodplain (Redford & Richter 1999). These ecological and physical structures and patterns are affected by the physical process of erosion and deposition that shape the landscape, and on a larger timescale by processes such as climatic change and tectonics. All these factors and processes are liable to be influenced by human intervention (Redford & Richter 1999).

The relationship between biodiversity, natural capital stocks, and ecosystem service flows is likely to be complex in this way for a wide variety of systems. Recent reviews confirm that there is still insufficient evidence to conclude that there is always a positive relationship between biodiversity and ecosystem function (Loreau *et al*. 2002; Thompson & Starzomski 2007). It is risky to conflate concerns about biological diversity with stocks of natural capital and flows of ecosystem services with which they might be associated in particular circumstances. If the delivery of specific (and valuable) ecosystem services is contingent on the presence of other favorable conditions, changes in those conditions might undermine the conservation case even though the biological importance of the relevant ecosystem remains unaltered.

Type of services and the stock-flow relationship

The second problem that we identify here is the way in which the relationship between stocks and flows varies with type of ecosystem service (Millennium Ecosystem Assessment 2005). In the case of regulating services (e.g., climate regulation) and supporting services (e.g., nutrient cycling), aggregate stocks are most important. The "efficiency" with which stocks deliver specific ecosystem services will vary with ecology. Thus a forest's capacity to provide climate regulation services will reflect broad patterns of species composition and architecture, but flows of services may not be closely linked to conservation value in terms of diversity across all taxa (Carnus *et al.* 2006). However, these outcomes may well be context-specific; for instance, recent modeling of ecosystem services in the forested Williamette Basin in Oregon, USA found little evidence of trade-offs between ecosystem services and biodiversity conservation: scenarios that enhanced conservation also enhanced services such as carbon sequestration, water quality, and soil conservation (Nelson *et al.* 2009).

In the case of provisioning services, aggregate stocks matter, but the magnitude and value of flows of services depends on the technology available to convert stocks into valuable supplies of goods. Differences in harvesting technologies can lead to different flows of outputs from similar stocks. Thus, in the case of fishing, the availability of powered boats for trawling, freezer capacity and sonar transform the ability of fishers to extract revenue from marine ecosystems. In timber concessions, chainsaws and powered haulage also change the scale and value of economic flows from a forest. In both cases, such technologies also, of course, have implications for sustainability of revenue flows. The value of provisioning service flows from a given stock of natural capital can therefore vary with the technology used. Technology is also important in demand for ecosystem services; this is discussed below.

The relationship between cultural services and stocks of biodiversity is a little more complex and can vary over time. Somewhat paradoxically, declining stocks can increase the marginal cultural values attached to surviving individuals of a particular species, suggesting an inverse relationship between the value of flows of services and the stock size. As the case of sturgeon demonstrates, rare species are often especially valued precisely because they are scarce (Gault *et al*. 2008), and, paradoxically for conservationists, stock recovery (abundance) may actually reduce the value of associated cultural service flows. Thus the income from tourism based on the reintroduction of a charismatic locally extinct species (e.g., the white-tailed sea eagle (*Haliaeetus albicilli*) to the UK) might be expected to decline as the species becomes widespread (as the red kite (*Milvus milvus*) has done in the UK).

The more general point is that economic theory predicts that value and scarcity are inversely related, and a simple application of these principles to conservation would suggest that species recovery and relative abundance can paradoxically result in reduced support for conservation. Moreover, different human actors may perceive the relationship between the size of stocks of biodiversity and the value of the flows of services that they provide differently. Thus, while conservationists may welcome the recovery of some species, other stakeholders may perceive them as a pest. For example, while conservationists celebrate the recovery of species such as the peregrine falcon (*Falco peregrinus*) in the wild in the UK, pigeon racers regard them as a serious threat (Dixon *et al.* 2003). Similarly, growth in the population of gray wolves (Canis lupus) reintroduced to Yellowstone National Park has evoked sustained local opposition (Nie 2003).

These relationships between biodiversity and valued ecosystem functions are an important area for further theoretical and experimental research (BRAG 2006). Arguments that promote conservation goals on the basis of presumptive relationships between biodiversity stocks and the different forms of ecosystem services may be premature.

Human demands and market values

The third problem with the application of thinking about ecosystem services to conservation to which we want to draw attention is the way in which the value of ecosystem services depends on human demand. The value of ecosystem service flows depends not on the intrinsic merits of the stock of biological capital, but on the existence and operation of a market.

This has several implications. First, the prices set for different services will reflect supply and demand, willingness to pay, and transaction costs. The market value of the services from biologically similar ecosystems will vary with the uses made of them. Thus Plummer (2009) describes a bottomland forest wetland used for wastewater treatment, which has a value reflecting its location near a potato chip factory. Other similar wetlands do not have an equivalent value: as he puts it "not all ecological systems are pearls of great price" (p. 38). Furthermore, these values can change over time, especially as a consequence of changing economic circumstances, which can equally strip ecosystems of their value. Thus, in the bottomland forest example, expansion of potato chip production eventually forced an alternative to wetland wastewater treatment, thereby removing its service value (Plummer 2009). While this example may not necessarily be typical of all wetlands, since these often provide multiple valuable services, it does point to the vulnerability of strategies based on markets for specific ecosystem services (once substitutes become available or necessary).

Second, once market values are associated with different stocks of natural capital, there is a risk that certain types of high value services will dominate management strategies (Carnus *et al*. 2006). Ecosystems may not have to be particularly diverse or pristine to deliver some ecosystem services (e.g., provisioning and regulating services). If these services are highly valued (because high demand exists) they may outweigh services associated with high biological diversity (often a public good and hence undervalued). If the ecosystem services in greatest demand (e.g., carbon) can be provided by landscapes that contain only small areas of pristine or highly diverse habitat (perhaps far less than the 12% of habitat currently in protected areas, Chape *et al.* 2008), these flows might be maintained (or enhanced) despite significant changes in biological stock. The persistence of biodiversity and the sustainability of ecosystems services are largely dependent on each other, but are not interchangeable (Egoh *et al.* 2007). Areas of highest diversity and highest service value are not congruent (Naidoo *et al.* 2008).

What happens to biodiversity if the most valuable services in a market sense (e.g., clean water supply, carbon sequestration) can be provided from substantially impoverished ecosystems (e.g., forests of exotic species with relatively few associated animal and plant species)? The delivery of a large proportion of economically valuable ecosystem services from a fundamentally altered stock might be economically efficient, but would be likely to run counter to the outcomes desired by conservation practitioners.

There are two further problems with the dependence of the value of ecosystem service flows on human demand, as expressed through markets: the importance of technologies and infrastructure, and second, the way markets for ecosystem services change over time.

Stocks of biological diversity only yield economically valuable ecosystem services when appropriate technologies and infrastructure exist to deliver these services to consumers, converting natural capital into ecosystem service to meet demand (e.g., an urban water distribution network). Without this, the value of the ecosystem services would be low or even zero. Thus the wildlife viewing tourist industry depends on the existence of stocks of local living diversity for tourists to see, but the flow of related ecosystem services depends on the technologies used to view nature (binoculars, televisions, computers, etc.) and the infrastructure to allow that viewing (hotels, airplanes, internet cabling etc.).

The revealed value of ecosystem services is not constant, but changes over time as market demand changes. Services such as carbon sequestration have only begun to be understood in recent decades, and even now markets are limited and prices are low. It is hard to predict what stock of biodiversity is (and will be in future) needed to provide new services, or services for which demand grows and whose value increases. Some stocks of natural capital may actually be destroyed or irreversibly damaged before their values have been understood, let alone valued and paid for.

Conclusion

The relationships between most ecosystem services and particular stocks of biodiversity are complex. Biological and nonbiological attributes of ecosystems affect flows of services, and the value of these flows will vary under different conditions. While, as a crude generalization, it is clearly true that many forms of ecosystem services depend on biodiversity and the ecological (and genetic and population) processes it comprises, changes in specific flows of ecosystem services need to be carefully associated with changes in particular species and ecosystems that comprise conservation priorities. Ecosystem service concepts are essentially based on anthropogenic values, which reflect changing consumer preferences, willingness to pay, and technologies.

There is therefore a strategic risk in justifying biodiversity conservation primarily in terms of ecosystem services, as McCauley (2006) pointed out. Although explicit modeling of ecosystem services suggests limited trade-offs between biodiversity and ecosystem service values in forested catchments in the USA, Nelson *et al.* (2009) warn that more striking trade-offs are likely in rapidly developing regions. It may therefore be sensible for conservationists to focus debate on the specific stocks of natural systems and processes that they are seeking to protect, instead of relying on a proxy indicator (flows of ecosystem services), which may be imperfectly related to these conservation goals. As Blignaut & Aronson (2008) have argued recently, biodiversity is of overarching importance, not just one ecosystem service among many. We support this view, and have provided further arguments that demonstrate the risks of confusion arising from a conceptual conflation of stock and flow concepts.

Continuing academic work that is seeking to explore the complex links between biodiversity, ecosystem function, system stability, and ecosystem service flows is usually cautious in its policy conclusions (Turner & Daily 2008). This is to be welcomed, and the growing stock of knowledge about ecosystems and their functioning may well expand the range of management possibilities that simultaneously serve the interests of biodiversity conservation and the promotion of human well-being. Policy makers and practitioners, however, need to be careful not to push too quickly on implementation of programs based on presumptive win–win scenarios. There is a risk that the silver bullet of ecosystem services may backfire, with high value ecosystem service functions being promoted at the expense of conservation priorities.

Acknowledgments

This article draws on discussions about ecosystem services with P. Dasgupta, S. Owens, K. Redford, members of the Cambridge Political Ecology of Development Group and the IIED Payment for Watershed Services project, and participants in the ESRC-NERC supported Ecosystem Services seminar at the Department of Geography in Cambridge in January 2008. We are grateful to the editors and two anonymous referees for their helpful comments on our original draft.

References

Adams, W.M., Hulme D. (2001) Conservation and communities: changing narratives, policies and practices in African conservation. Pages 9–23 in D. Hulme, M. Murphree, editors. *African wildlife and livelihoods: the promise and performance of community conservation.* James Currey, London.

Armsworth, P.R., Chan K.M.A., Daily G.C. *et al*. (2007) Ecosystem service science and the way forward for conservation. *Conserv Biol* **21**, 1383–1384.

Aylward, B. (2005) Towards watershed science that matters. *Hydrol Process* **19**, 2643–2647.

Blignaut, J., Aronson J. (2008) Getting serious about maintaining biodiversity. *Conserv Lett* **1**, 12–17.

BRAG. (2006) *Research needs analysis for the role of biodiversity in ecosystem function*. UK Biodiversity Research Advisory Group.

Bruijnzeel, L. (2004) Hydrological functions of tropical forests: not seeing the soil for the trees? *Agr Ecosyst Environ* **104**, 185–228.

Chape, S., Spalding M., Jenkins M. (2008) *The World's Protected Areas: status, values, and prospects in the twenty-first century*. University of California Press, Berkeley, CA.

Carnus, J.M., Parrotta J., Brockerhoff E. *et al*. (2006) Planted forests and biodiversity. *J Forest* **104**, 65–77.

Daily, G.C., Söderqvist T., Aniyar S. *et al*. (2000) The value of nature and the nature of value. *Science* **289**, 395–396.

Daily, G.C., Polasky S., Goldstein J. *et al*. (2009) Ecosystem services in decision making: time to deliver. *Front Ecol Environ* **7**, 21–28.

Dixon, A., Richards C., Lawrence A., Thomas M. (2003) Peregrine (Falco peregrinus) predation on racing pigeons (Columba livia) in Wales. Pages 255–261 in D.B.A. Thompson, S.M. Redpath, A.H. Fielding, M. Marquiss, C.A. Galbraith. *Birds of prey in a changing environment*. The Stationery Office, Edinburgh, 2003.

Egoh, B., Rouget M., Reyers B. *et al*. (2007) Integrating ecosystem services into conservation assessments: a review. *Ecol Econ* **63**, 714–721.

Gault, A., Meinard Y., Courchamp F. (2008) Consumers' taste for rarity drives sturgeons to extinction. *Conserv Lett* **1**, 199–207.

Landell-Mills, N., Porras I.T. (2002) *Silver Bullet or Fool's Gold?: A global review of markets for forest environmental services and their impacts on the poor*. International Institute for Environment and Development, London.

Loreau, M., Naeem S., Inchausti P. (2002) Biodiversity and ecosystem functioning: current knowledge and future challenges. *Science* **294**, 804–808.

McCauley, D.J. (2006) Selling out on nature. *Nature* **443**, 27–28.

Miles, L., Kapos V. (2008) Reducing greenhouse gas emissions from deforestation and forest degradation: global land-use implications. *Science* **320**, 1454–1455.

Millennium Ecosystem Assessment. (2005) *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington.

Naidoo, R., Balmford A., Costanza R. *et al*. (2008) Global mapping of ecosystem services and conservation priorities. *Proc Natl Acad Sci USA* **105**, 9495–500.

Nelson, E., Mendoza G., Regetz J. *et al*. (2009) Modeling multiple ecosystem services, biodiversity conservation, commodity production and tradeoffs at landscape scales. *Front Ecol Environ* **7**, 4–11.

Nie, M.A. (2003) *Beyond wolves: the politics of wolf recovery and management*. University of Minnesota Press, Minneapolis.

Plummer, M.L. (2009) Assessing benefit transfer for the valuation of ecosystem services. *Front Ecol Environ* **7**, 38–45.

Redford, K.H., Richter B.D. (1999) Conservation of biodiversity in a world of use. *Conserv Biol* **13**, 1246–1256.

Reid, W.V., Mooney H.A., Capistrano D. *et al*. (2006) Nature: the many benefits of ecosystem services. *Nature* **443**, 749.

Sidle, R.C., Tani M., Ziegler A.D. (2006) Catchment processes in Southeast Asia: atmospheric, hydrologic, erosion, nutrient cycling and management effects. *Forest Ecol Manag* **224**, 1–4.

Thompson, R., Starzomski B.M. (2007) What does biodiversity actually do? A review for managers and policy makers. *Biodivers Conserv* **16**, 1359–1378.

Turner, R.K., Daily G.C. (2008) The ecosystem services framework and natural capital conservation. *Env Res Econ* **39**, 25–35.

Wilson, E.O. (1992) *The diversity of life*. Harvard University Press, Cambridge, MA.

Wunder, S. (2006) The efficiency of payments for environmental services in tropical conservation. *Conserv Biol* **21**, 48–58.

Editor: Dr. James Blignaut

