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Conservation and Human Welfare: Economic Analysis of Ecosystem Services

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The importance of the links between well-functioning ecosystems and human well-being are clearly evident in our age of rapidly changing environmental and socio-economic conditions. And yet, the role ecosystems play in supporting and sustaining human welfare has been only a marginal area of study to date in the field of economics (Dasgupta 2010). But this is starting to change. Millennium Ecosystem Assessment (2005) and the burgeoning literature on ecosystem services that has followed, largely instigated by work in ecology, has begun to percolate into economics. The number of articles by economists on various aspects of ecosystem services, including the benefits of conserving ecosystems and biodiversity, tradeoffs among services, payments for ecosystem services (PES) and other incentive mechanisms, has risen dramatically in the past several years. Still, the economics literature on ecosystems and biodiversity is nowhere near as prominent as the economics literature on climate change. Economists have played a central role in defining the key elements of the debate on climate change following publication of the Stern Review (Stern 2007) and the ensuing debates (e.g., Nordhaus 2007; Sterner and Persson 2008; Weitzman 2007). Economists have yet to play such a central role in ecosystem services and biodiversity.

Ecosystems provide a wide range of benefits, from the water and climate regulation roles of forests, the waste assimilation and storm regulation capacities of wetlands, to the cultural and aesthetic benefits derived from savannas. Ecosystems processes and raw materials are

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essential in food, fuel and fiber production but also for pest control, pollination services and recreational opportunities. However, there are often tradeoffs among ecosystem services. Woodlands in sub-Saharan Africa become fields of maize to feed those faced with food insecurity. Coastal wetlands become housing and recreation hotspots, or shrimp farms. These choices imply an increase in some services (e.g., food production) are traded for decreases in other services (e.g., carbon sequestration, storm protection). These tradeoffs often pose difficult choices for society, with different sets of winners and losers depending on the decision. Frequently there is a difference between the social and private benefits of such decisions. There is, therefore, a critical role for economic analysis, integrated with natural science, to underpin policy.

Advances in the natural sciences and environmental economics, as well as better linkages between the two, allow better understanding of how human actions affect ecosystems and biodiversity, and in turn how changes in ecosystems and biodiversity affect human welfare. Work by ecologists has improved our understanding of "ecological production functions" that link structure and function of ecosystems with the provision of ecosystem services. For example, recent work has provided evidence on how upslope vegetation affects the timing, quality and value of water to various downstream users (Guo et al. 2000). Integrated teams have increased our understanding of the chain from human actions through ecosystems back to human welfare. For example, integrated work has shown how the social and ecological effects of "waves" of resource extraction affect marine fisheries (Pauly et al. 1998) and coastal forests (Ahrends et al. 2010) and their implications for human welfare. Recent studies have analyzed the tradeoffs across multiple ecosystem services at scales local, regional and global scales (Hein et al. 2006; Naidoo et al. 2008; Nelson et al. 2009). While progress is being made in the integration of economics and ecological sciences for understanding ecosystem services, this is still a field in its nascent stage. Our ability to deliver robust science for decision-making at the necessary policy relevant scales, while growing rapidly, remains limited (Daily et al. 2009).

Two critical areas of research for more fully understanding the links between our management and use of natural systems and our own welfare are:

(1) *How can we robustly model multiple and linked ecosystem processes and services in the context of human decision making (Carpenter et al. 2006)?* For example, it is obvious that deforestation affects the ability of an ecosystem to store and sequester carbon as well as its ability to produce timber now and in the future, but how does it simultaneously affect stream flow, timing and quality? How are pollination services and pest control affected? How do species compositions and local weather patterns change? On the welfare side, who gains the benefits of deforestation and who loses services previous supplied? What is value associated with these gains and losses? How are the costs and benefits distributed across the landscape and across time? These are the kinds of complex questions that stem from considering a simple land use change in light of ecosystem services and human welfare. Gaining more complete understanding of the entire set of consequences requires integrated conceptual frameworks for assessment and spatially and temporally explicit models.

An important part of this complex issue is the role of biodiversity or individual species in delivering ecosystem services and hence human welfare (Carpenter et al. 2006; Sutherland et al. 2009). Micro and meso-scale experiments have shown that increased biodiversity positively affects ecosystem processes like nutrient retention, decomposition and primary productivity (Naeem et al. 1994; Tilman et al. 1996; Solan et al. 2004; Tilman et al. 2006). Some studies have linked the conservation of habitat with increases in provision of services, like pollination, with direct financial returns (Ricketts et al. 2004), and increased biodiversity with ecosystem service provision (Tilman et al. 2005). Other recent work discusses the insurance value of a more diverse assemblage arguing that "more species are needed to *insure* a stable supply of ecosystem goods and services as spatial and temporal variability increases…" (Hooper et al. 2005). But others have questioned about the generality of empirical results derived from specific systems (Pfisterer and Schmid 2002) and quantification of the insurance value or other values of conserving biodiversity remain open issues. In addition, what are the costs of species-led conservation initiatives in terms of reductions in other services and do the conservation benefits warrant incurring these costs?

(2) *How does conservation and changes in ecosystem service flows affect welfare and what policy instruments can we use to manage these services equitably and efficiently. Of particular practical and ethical relevance are the impacts on the poor (Carpenter et al. 2006; Adams et al. 2004).* At the global scale there is a high level of correlation among the world's most biodiverse places (Humid Tropics), places where land-use change is the greatest, and several different indicators of poverty (Myers et al. 2000; Smith et al. 2003; Fisher and Christopher 2007; Sodhi et al. 2010). In places where such overlap is present any conservation intervention or change in ecosystem service delivery is going to have consequences for both biodiversity and poor people. In some cases actions good for biodiversity conservation might also serve to alleviate poverty. In other cases, protecting a forest might conserve species and serve carbon-related objectives, but foreclose opportunities for the poor (e.g. fuelwood collection or hunting).

From an operational viewpoint the most important issue is how we can design policies and institutions to efficiently manage ecosystems to sustain an equitable provision of ecosystem service (Carpenter et al. 2006). Even with an understanding of ecological complexities, if we lack the proper institutional context to provide incentives for the provision of public goods and internalize externalities we will not succeed at efficient and sustainable management of ecosystems. Only institutions, be they formal government regulation, market-like mechanisms such as catch-shares or individually tradable quotas, or informal norms and customs of self-regulation, can save a fishery or other common property resource from the "tragedy of the commons" (Ostrom 1990; Dietz et al. 2003; Costello et al. 2008). In addition, since many issues have important temporal and risk dimensions, issues of discount rates, and decision-making under uncertainty, and how we design institutions to handle risk and understanding and discounting are vitally important. These issues, in fact, are dominant issues in the economic debate on climate change and they are similarly present and important for a good analysis of ecosystem management.

In this special issue *"Conservation and Human Welfare: economic analyses of ecosystem services"* the collection of papers go some way in moving the field forward in both of these critical areas.

Balmford et al. provide a comprehensive framework with the specific goal of guiding assessment on the economic effects of losing biodiversity and ecosystem services. This type of assessment was called for at a global scale by the G8+5 nations, inspired by the policy relevance of the Stern Review. There are several key insights from this paper: the importance (if adding economic values across services) of taking care to consider any overlapping contributions they make to well-being in order to avoid double-counting; the need to factor-in not just changes in benefit flows but the costs of conservation; the need for analyses to be spatially explicit, taking into account as far as possible variation in the production, flow and value of services (rather than, for example, taking biome-wide average values); and the importance of focusing not on the gross values of services but how they would differ between two states of the world: one involving the action of interest (such as reducing forest loss by X%) and a second, otherwise identical counterfactual state based on business as usual. It is the difference in service delivery between these states, summed (where appropriate) across services and net of the costs of the action, that is of most relevance to decision-makers.

The framework leads us through mapping the services in a given future, quantifying the differences for that service between scenarios and then imputing an economic value for that difference. A final map for such an assessment would show the net economic consequences of choosing one scenario over the other and in turn enable further questions to be tackled. What are the effects of the action on global or national GDP? What might be the effects on poverty, equity or regional stability? One final, overarching point made by the paper is that full global assessments of this sort are likely to be an impossibility given the current state of knowledge regarding our linked socio-ecological systems. However, the paper ends with an expert review (involving > 50 scientists and economists) of how close we are to be able to carry out such assessments globally for 17 key ecosystem services and benefits. This concludes that we have the relevant ecological and socio-economic data and models to be able to deliver preliminary global-scale assessments of the impacts of major policy interventions on three services: marine fisheries production, global climate regulation and wild meat provision.

Similar to Balmford et al., Bateman et al. provide a methodology designed to drive a large-scale ecosystem service assessment: The UK's National Ecosystem Assessment. The paper has several elements which bear on the central themes of this special issue. First, it acts as an introduction to the successor to the UN's *Millennium Ecosystem Assessment*. Second, it provides a primer on the principles and concepts of economics required in an ecosystem service assessment. Third, the paper addresses the importance of incorporating concerns regarding sustainability within any such assessment. Any analysis of the current state of our environmental and biological assets should precipitate the question "Are current trends sustainable?" Bateman et al. address this by considering both the sustainability of historic trends and future scenarios under which sustainability can be assessed.

Bateman et al. also produce a case study assessing the financial and economic values of a suite of ecosystem services including timber, carbon storage, recreation and agriculture against a land use change scenario. Applying the principles of their paper across a relatively substantial case study area, the assessment allows decision makers to consider the consequences of a variety of policy options. Findings of such analyses are presented in mapped outputs, for example, showing locations where forest cover would produce higher economic values than agriculture and vice versa. Extending this, a map optimized for social net present value is then compared to the actual land use matrix so as to highlight where the market values of agriculture have dominated compared to the economic values of a more socially optimal landscape. This highlights the results that agricultural subsidies have marginalised forestry to upland areas, even though many of these are highly unsuitable for such woodlands and indeed can lead to net losses of carbon as trees are planted upon and dry out upland peatbogs. Finally, the paper delivers an informed discussion on some of the current limitations of ecosystem service assessments ranging from our lack of ecological production functions and scant spatial coverage of valuation studies to analysis dependent issues like discounting and equity weighting.

Polasky et al. move us from conceptual frameworks to quantifying changes in ecosystem services, species habitats and agricultural returns in Minnesota from 1992–2001. The authors use a spatial explicit integrated model (InVest) to quantify the actual changes on the landscape over this time period and compare them against a suite of alternative scenarios.

The model uses land cover, biophysical and economic data as the basis for generating the values for several ecosystem services - carbon storage, water quality, habitat provision and agricultural production. For example, the agricultural production value of a pixel is derived from the land cover type (relating soil attributes), expected yields on that pixel and crop price (less cost).

The five scenarios against which the actual change values are compared give an indication of the potential values the landscape could have generated over the same time frame. The scenarios investigated are *no urban expansion*; *no agricultural expansion*; *agricultural expansion*; *forest expansion*; and a *conservation* scenario where riparian areas and marginal agricultural areas are restored to the native vegetation. The analysis sheds light on the private versus social values that can be captured in such a context as Minnesota. For example, the agricultural expansion scenario, where all highly productive land is put into agriculture, delivers the lowest total value across all scenarios, in spite of the fact that it delivers the highest financial return to landowners in the form of crop sales. This result is due to the negative impacts such an expansion would have on carbon storage and water quality. The lack of concordance between social and private values in this assessment empirically supports the typical assumption of ecosystem service research, that land use decisions would likely be different if a wider set of goods and services were considered.

Sanchirico and Springborn also move the science of ecosystem services forward in the area of simultaneously assessing multiple ecosystem services. They use a bioeconomic model of a coral reef-mangrove-seagrass system to investigate the role that mangroves play as both a storm protection service and as a nursery for coral reef fish. They also incorporate market values of converting mangroves into aquaculture—the goal being an optimal path of mangrove management to maximize values from fishing, aquaculture and storm regulation.

The authors look at the role in which payments for ecosystem services (PES) can play in delivering the optimal mangrove management. They have several important insights to share. First, they show that in contexts where multiple services are interdependent, internalized private values (storm protection in this case) mitigate the level of PES payments needed to ensure the delivery of other services. This result highlights the importance of including multiple ecosystem services (when they are interdependent), across beneficiaries, in order to minimize financial payments across groups. Their bioeconomic model also suggests that in the case of a degraded coral reef-mangrove-seagrass system the necessary payments to conserve the mangrove system are likely to be greater than the gains from the fishery. Understanding the current and future state of the ecosystem in this case is critical to knowing if a PES systems can be financially sustainable or will need to be subsidized in the long run. Both of these results not only shed light on the importance of modeling multiple ecosystem services, but also another key area mentioned above—the significance of conservation on the poor or marginalized—a prominent issue since large mangrove systems occur in the developing world where many poor rely on local fisheries and a suite of other goods and services provided by mangroves.

Ferraro and Hanauer also tackle the question about how conservation, or the provision of certain ecosystem services, affects the poor. The authors' main goal is to see how protected areas (i.e. forest conservation) affect deforestation and poverty outcomes in Costa Rica. Building on the work of Andam et al. (2008), which showed protected areas reduced deforestation and Andam et al. (2010), which showed that poverty was lower in census tracks with greater than 10% forest cover protected areas, this study looks at how biophysical and socio-economic variables shape conservation and poverty outcomes. For protected areas established prior to 1980, the authors compare poverty alleviation and avoided deforestation across a set of subgroup variables to tease out average treatment effects.

The subgroup variables that they test for statistical differences are land use capacity, slope, distance to major city, percent agricultural workers and initial poverty.

The authors find that avoided deforestation is higher when protected areas occur in places with high suitability for agriculture, are far from major cities and have a higher than average percentage of their workers employed in agriculture. Despite the fact that deforestation is higher in such areas, the avoided deforestation (compared to an expected amount) is about three times higher than in areas with low agricultural capacity, are close to cities and have a lower than average percentage of workers in agriculture. However, the authors also find that higher poverty alleviation is associated with protection that occur in areas with the opposite characteristics of the higher avoided deforestation set, i.e. poverty alleviation is higher when protected areas occur in places with low capacity agriculture, are close to cities and have fewer workers employed in agriculture. Additionally the authors find that the effects of protection on deforestation and poverty were not statistically different in high versus low baseline poverty areas. However, in the high poverty areas, both the avoided deforestation effect and poverty alleviation effect were positive and statistically different from zero.

The result here suggests that 'win-wins' in terms of poverty alleviation and conservation outcomes do exist, but emphasis on one outcome may come at a cost to the other. The results also lend support to the argument in the literature that protected areas are unlikely to exacerbate poverty given the locations in which they tend to be established.

Both of the two following papers focus on the role of institutions, instruments or contracts to mitigate the potential conflicts between wildlife and (local) humans. Zabel et al. also deals with an issue that sheds lights on both the poverty-conservation issue and the role that individual species play in ecosystem service provision and hence human welfare. They investigate a situation where the conservation of a large carnivore has the potential to impact livestock and livelihoods and also instigate retaliatory killing—mitigating the success of any species led intervention. Policy interventions for such a situation include compensation payments for lost revenues due to attacks on livestock and performance based payments which reward specific wildlife outcomes (e.g. target species population size). The authors explore both of these approaches and compare implementation costs as well as incentives for optimal livestock protection.

Zabel et al. advance the modeling approach in this field by considering both lethal and non-lethal livestock protection and retaliation strategies. They find support for the theoretical intuition that compensation payments can deliver enough incentive to deter retaliatory hunting. However, they simultaneously encourage sub-optimal livestock protection. The performance-based payments are not found to distort livestock protection levels, but in some contexts are likely to have high transaction costs. The authors close with an illustrative example with data on tiger-livestock conflicts in India suggesting that in such a context compensation payments might be a cheaper policy option for a given optimal tiger population.

Fischer et al. also study the intricacies of policy making in the area of conservation and its implications for human welfare by formulating a bioeconomic model of a conservation benefit-sharing program. They make reference to the CAMPFIRE program in Zimbabwe as one empirical example, and look at tourism and hunting as the revenue generating activities, but also acknowledge that conservation represents an opportunity cost via lost agricultural production. They specify a model where wildlife stocks are moderated by the number of hunting licenses available, poaching and of particular importance is the effort of the local community to discourage poaching. Unless the local community perceives benefits from conservation, they are unlikely to discourage poaching and since their collaboration is crucial to the success of any serious conservation efforts, it also becomes crucial to make sure that the welfare of the local community is taken into account.

The analysis provides a range of insights for the important conservation-poverty issue mentioned above. Revenue sharing is of course a good first step but it does not automatically benefit local communities enough or incentivize them in a correct way towards conservation. For example, if communities were allocated revenue shares from both hunting and tourism, this would per se appear to make them more prone to discourage poaching. However incentives are really more complicated which can be illustrated by considering the effect on welfare of a larger wildlife stock. Unless the communities also have a say in the allocation of hunting licenses—and thus a direct say in determining the total stock of wildlife, they are likely to be hurt if the Parks Agency wants really large wildlife stocks. Although they would get a share of revenue, this effect would be dominated by soaring wildlife damages to local agriculture. If communities received revenue from hunting, but park agencies held power to license hunting then the latter might attempt to maximize profits from tourism and minimize hunting levels thus, conferring the benefit largely to the agency and not the community. However if the communities can influence the decisions, improved agricultural rents and shares in hunting and tourism revenue do truly benefit the community. However the exact incentives depend on which profits are shared, if the profits outweigh the lost agricultural rents and how the communities respond to the program (i.e. self-monitoring poaching activities). As in many other areas of economic policy, the exact design of incentives is important and faulty design can lead to perverse incentives.

Naidoo et al. also explore the role in which biodiversity conservation affects community welfare. Their research from conservancies in Namibia combines wildlife and economic surveys, bringing the two streams together to see if diversity per se has an effect of the financial revenue captured by conservancies. The effect that diverse assemblages of species has on ecosystem functioning and services has been investigated at the micro and mesocosm scale (see above), but it has not seen evidence from conservation relevant scales nor relating to the financial returns to communities. This is where Naidoo et al. add to the literature.

They use nonmetric multidimensional scaling (NMDS) techniques to characterize conservancies with regards to wildlife profiles and regression models to predict financial benefits. Their model explains 91% of the variation in financial returns to conservancies, with the structure and diversity of the wildlife on a conservancy having the strongest contribution. Here we have direct evidence that higher levels of biodiversity can indeed drive higher levels of financial benefits. The authors explain the result suggesting that the more diverse conservancies provide a greater range of hunting and viewing options for tourism and suggest that encouraging a range of species might be a lucrative management agenda for conservancies.

Taken together, the suite of papers compiled in this special issue adds an evidence-base to several key areas of ecosystem services research. Issues range from individual species conservation and ecosystem service bundling to a global scale assessment framework. The papers demonstrate how conservation and human welfare are related across space, time, level of development, and governance systems. Each article integrates an ecological understanding with economic insight, while elucidating tradeoffs when they exist. The articles focus on knowledge that is useful for the design of institutions or policies that may contribute to ecosystem conservation and livelihood benefits on the ground. In doing so they make policy relevant contributions. While economists have yet to play a central role in the debate on ecosystem services and biodiversity, we hope that the works collected here go some way towards increasing the role of economic insight in ecosystem service-related decision making.

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References

Adams WM, Aveling R, Brockington D, Dickson B, Elliott J, Hutton J, Roe D, Vira B, Wolmer W (2004) Biodiversity conservation and the eradication of poverty. Science 306:1146–1149

Ahrends AND, Burgess MSAH, Bulling MT, Fisher B, Smart JCR, Clarke GP, Mhoro BE, Lewis SL (2010) Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. Proc Nat Acad Sci USA 107:14556–14561

Andam KS, Ferraro PJ, Pfaff A, Sanchez-Azofeifa GA, Robalino JA (2008) Measuring the effectiveness of protected area networks in reducing deforestation. Proc Nat Acad Sci USA 105:16089–16094

Andam KS, Ferraro PJ, Sims KRE, Healy A, Holland MB (2010) Protected areas reduced poverty in Costa Rica and Thailand. Proc Nat Acad Sci USA 107:9996–10001

Balmford A, Fisher B, Green RE, Naidoo R, Strassburg BBN, Turner RK, Rodrigues ASL (this issue) Bringing ecosystem services into the real world: an operational framework for assessing the economic consequences of losing wild nature. Environ Resour Econ

Bateman IJ, Mace GM, Fezzi C, Atkinson G, Turner RK (this issue) Economic Analysis for Ecosystem Service Assessments. Environ Resour Econ

Carpenter SR, DeFries R, Dietz T, Mooney HA, Polasky S, Reid WV, Scholes RJ (2006) Millennium ecosystem assessment: research needs. Science 314:257–258

Costello C, Gaines SD, Lynham J (2008) Can catch shares prevent fisheries collapse? Science 321:1678–1681

Daily GC, Polasky S, Goldstein J, Kareiva PK, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R (2009) Ecosystem services in decision making: time to deliver. Front Ecol Environ 7:21–28

Dasgupta P (2010) 20th Anniversary of EAERE: the European association of environmental and resource economists. Environ Resour Econ 46:135–137

Dietz T, Ostrom E, Stern PC (2003) The struggle to govern the commons. Science 302:1907–1912

Ferraro PJ, Hanauerz MM (this issue) Protecting ecosystems and alleviating poverty with parks and reserves: win-wins or tradeoffs? Environ Resour Econ

Fischer C, Muchapondwa E, Sterner T (this issue) A bio-economic model of community incentives for wildlife management under CAMPFIRE. Environ Resour Econ

Fisher B, Christopher T (2007) Poverty cand biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. Ecol Econ 62:93–101

Guo ZW, Xiao XM, Li DM (2000) An assessment of ecosystem services: water flow regulation and hydroelectric power production. Ecol Appl 10:925–936

Hein L, van Koppen K, de Groot RS, van Ierland EC (2006) Spatial scales stakeholders and the valuation of ecosystem services. Ecol Econ 57:209–228

Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, Lavorel S, Lawton JH, Lodge DM, Loreau M, Naeem S, Schmid B, Setala H, Symstad AJ, Vandermeer J, Wardle DA (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol Monogr 75:3–35

Millennium Ecosystem Assessment (2005) Island Press, Washington, DC

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Naeem S, Thompson LJ, Lawler SP, Lawton JH, Woodfin RM (1994) Declining biodiversity can alter the performance of ecosystems. Nature 368:734–737

Naidoo R, Balmford A, Costanza R, Fisher B, Green RE, Lehner B, Malcolm TR, Ricketts TH (2008) Global mapping of ecosystem services and conservation priorities. Proc Nat Acad Sci USA 105:9495–9500

Naidoo R, Stuart-Hill G, Weaver LC, Tagg J, Davis A, Davidson A (this issue) Effect of diversity of large wildlife species on financial benefits to local communities in northwest Namibia Environ Resour Econ

Nelson E, Mendoza G, Regetz J, Polasky S, Tallis H, Cameron DR, Chan KMA, Daily GC, Goldstein J, Kareiva PM, Lonsdorf E, Naidoo R, Ricketts TH, Shaw MR (2009) Modeling multiple ecosystem services biodiversity conservation commodity production and tradeoffs at landscape scales. Front Ecol Environ 7:4–11

Nordhaus WD (2007) A review of the stern review on the economics of climate change. J Econ Liter 45(3): 686–702

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres F (1998) Fishing down marine food webs. Science 279:860–863

Pfisterer AB, Schmid B (2002) Diversity-dependent production can decrease the stability of ecosystem functioning. Nature 416:84–86

Polasky S, Nelson E, Pennington D, Johnson KA (this issue) The impact of land-use change on ecosystem services biodiversity and returns to landowners: a case study in the State of Minnesota. Environ Resour Econ

Ricketts TH, Daily GC, Ehrlich PR, Michener CD (2004) Economic value of tropical forest to coffee production. Proc Nat Acad Sci USA 101:12579–12582

Sanchirico JN, Springborn M (this issue) How to get there from here: ecological and economic dynamics of ecosystem service provision. Environ Resour Econ

Smith R, Muir R, Walpole M, Balmford A, Leader-Williams N (2003) Governance and the loss of biodiversity. Nature 426:67–70

Sodhi NS, Posa MRC, Lee TM, Bickford D, Koh LP, Brook BW (2010) The state and conservation of Southeast Asian biodiversity. Biodiver Conserv 19:317–328

Solan M, Cardinale BJ, Downing AL, Engelhardt KAM, Ruesink JL, Srivastava DS (2004) Extinction and ecosystem function in the marine benthos. Science 306:1177–1180

Stern N (2007) The economics of climate change: the stern review. Cambridge University Press, Cambridge

Sterner T, Persson UM (2008) An even sterner review: introducing relative prices into the discounting debate. Rev Environ Econ Policy 2(1):61–76

Sutherland WJ, Adams WM, Aronson RB, Aveling R, Blackburn TM, Broad S, Ceballos G, Cote IM, Cowling RM, Da Fonseca GAB, Dinerstein E, Ferraro PJ, Fleishman E, Gascon C, Hunter M, Hutton J, Kareiva P, Kuria A, MacDonald DW, MacKinnon K, Madgwick FJ, Mascia MB, McNeely J, Milner-Gulland EJ, Moon S, Morley CG, Nelson S, Osborn D, Pai M, Parsons ECM, Peck LS, Possingham H, Prior SV, Pullin AS, Rands MRW, Ranganathan J, Redford KH, Rodriguez JP, Seymour F, Sobel J, Sodhi NS, Stott A, Vance-Borland K, Watkinson AR (2009) One hundred questions of importance to the conservation of global biological diversity. Conserv Biol 23:557–567

Tilman D, Polasky S, Lehman C (2005) Diversity productivity and temporal stability in the economies of humans and nature. J Environ Econ Manag 49(3):405–426

Tilman D, Reich PB, Knops JMH (2006) Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature 441:629–632

Tilman D, Wedin D, Knops J (1996) Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379:718–720

Wardle DA, Walker LR, Bardgett RD (2004) Ecosystem properties and forest decline in contrasting long-term chronosequences. Science 305:509–513

Weitzman ML (2007) A review of the stern review on the economics of climate change. J Econ Liter 45(3):703–724

Zabel A, Pittel K, Bostedt G, Engel S (this issue) Comparing conventional and new policy approaches for carnivore conservation—theoretical results and application to tiger conservation. Environ Resour Econ