The promise and perils of payments for ecosystem services

Jim Salzman

Duke Law School,
Nicholas School of Environment and Earth Sciences,
Duke University, Box 90360,
Durham, NC 27708, USA
Fax: +1-919-613-7231
E-mail: Salzman@law.duke.edu

Abstract: Created by the interactions of living organisms with their environment, ecosystem services support our society by providing clean air and water, decomposing waste, pollinating flowers, regulating climate and by supplying a host of other benefits. Yet, with rare exception, ecosystem services are neither prized by markets nor explicitly protected by the law. In recent years, an increasing number of initiatives around the world have sought to create markets for services, some dependent on government intervention and some created by entirely private ventures. These experiences have demonstrated that investing in natural capital rather than built capital, can make both economic and policy sense. While markets for ecosystem services hold great potential, they also create challenges. This paper identifies the different types of service markets and examines the challenges created by each, focusing on moral hazards, rent-seeking, free riders and perverse incentives.

Keywords: ecosystem services; markets; environmental protection; natural capital; subsidies; perverse incentives.

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Biographical notes: Jim Salzman is a Professor with joint appointments at the Law School and Nicolas School of Environment and Earth Sciences at Duke University. The first Harvard graduate to earn joint degrees in Law and Engineering, he was named a Sheldon Fellow upon graduation. Prior to academia, he worked in Paris in the Environment Directorate of the Organization for Economic Cooperation and Development (OECD) and in London as the European Environmental Manager for Johnson Wax. He has advised the OECD, UNEP, EPA and the US Trade Representative on a range of policy issues. Elected as a Fellow of the Royal Geographical Society, he has lectured on environmental policy in the Americas, Europe, Asia, Australia and Africa. He has published papers in legal, scientific and popular journals as well as co-authored the leading textbook on international environmental law. He has served as a visiting Professor at Stanford, Harvard, Yale and the University of California, Santa Barbara. In 2002–2003, he served as a Fulbright Senior Scholar at Macquarie University in Australia.

1 Introduction

Healthy ecosystems provide a range of critical services that we largely take for granted. Created by the interactions of living organisms with their environment, these 'ecosystem services' underpin society by purifying air and water, detoxifying and decomposing waste, renewing soil fertility, regulating climate, mitigating droughts and floods, controlling pests and pollinating vegetation (Gretchen Daily Edition, 1997). Although awareness of ecosystem services dates back to Plato, and likely earlier, ecologists and economists have only recently begun systematically examining the extent and value of these services' contributions to social welfare. Not surprisingly, their research has demonstrated the extremely high costs to replace many of these services if they were to fail, on the order of billions of dollars in the USA for pollination alone (Costanza et al., 1997). One can dispute over the inherent uncertainty of such monetary estimates, but the high costs required to substitute for these services by artificial means are beyond dispute (Pearce, 1998; Salzman, 1997).

One cannot begin to understand flood control, for example, without realising the impact that widespread wetland destruction has had on the ecosystem service of water retention (Myers, 1997; The Trust for Public Land, 2000); nor can one understand water quality without recognising how development in forested watersheds has degraded the service of water purification (Ewel, 1997; The Trust for Public Land, 1998a). The costs from degradation of these services are high, and suffered in rich and poor countries alike.[1] Given their significance, one might expect that ecosystem services would be prized by markets and explicitly protected by the law. With few exceptions, however, neither has been the case. Our unthinking reliance on ecosystem services is due in part, no doubt, to society's dissociation between milk cartons and medicines in our home and the services of nutrient cycling and biodiversity that made these possible.

The primary reason why ecosystem services are taken for granted, however, is that they are free. We explicitly value and place dollar figures on certain 'ecosystem goods', such as timber and seafood. Yet, the services underpinning the production of these goods almost without exception have no market value – not because they are worthless but, rather, because there is no market to capture and express their value directly. No efficient price mechanisms exist to signal scarcity or deterioration of ecosystem services. They are classic public goods, neither directly 'consumed' nor exchanged in markets. These circumstances make ecosystem services easy to forget and hard to imagine disrupting beyond repair, until they fail. As a result, few significant markets have arisen that capitalise on the commercial value of these services.

This is starting to change, however. From their origins as an obscure phrase just nine years ago, 'ecosystem services' have gone mainstream, with new initiatives and markets for provision of services blossoming around the world.[2] The United States Environmental Protection Agency (EPA), for example, has created a Science Advisory Board on Valuing the Protection of Ecological Systems and Services (Science Advisory Board, 2003). In Australia, a high-level advisory body, known as The Wentworth Group, has called for a new approach to environmental protection that focuses on provision of ecosystem services (The Wentworth Group, 2002). In Costa Rica, the government is administering a nationwide scheme of payments for services (Pagiola, 2002). The international climate change negotiations are closely focusing on policy instruments that encourage carbon sequestration (United Nations Framework Convention on Climate Change). And this is just the tip of the iceberg. A recent study documented 287 cases of

payments for forest ecosystem services from around the world[3] and an international marketplace website for services, known as the Ecosystem Marketplace, has just been launched.[4]

If one surveys the range of ecosystem service markets in the field, they generally fall into three categories: mitigation markets, purely business-to-business (B2B) markets and government payment markets. In the paragraphs that follow, I describe these types of markets and then assess the potential problems posed by paying for services.

Mitigation markets are purely government-constructed markets. In order to receive a necessary permit to develop land, for example, parties must either ensure land is restored to mitigate for the loss of habitat and (in some cases) loss of services from the proposed development. The best examples of such markets may be found in US wetlands mitigation banking and the proposed Clean Development Mechanism (CDM) of the Kyoto Protocol. On its face, the primary American law conserving wetlands, the Clean Water Act (CWA), seems to prevent the filling of most wetlands.[5] The CWA provides a limited exception, however, through a permit system administered principally through the Army Corps of Engineers (the Corps).[6] These '404 permits' are necessary for many routine land development activities before they can proceed. When applying for a permit, a developer must convince the Corps that no reasonable alternatives exist to the development of the wetlands, that the design of the development minimises harm to the wetlands, and, if these two conditions have been satisfied, that other wetlands have been restored to compensate for the wetlands destroyed (known as 'compensatory mitigation') (Salzman and Ruhl, 2000a).

Wetlands mitigation banking allows a developer who has restored a wetland somewhere else in advance of development to draw from the resulting bank of mitigation 'credits' as the development is implemented and wetlands are filled (Salzman and Ruhl, 2000b). Wetland mitigation banking now resembles a commodity market, with freewheeling, entrepreneurial wetlands banks offering for sale finished off-site wetlands as 'credits' to anyone who is in need of mitigation for their 404 permits. There were between 370 and 400 such commercial mitigation banks operating in the USA as of January 2000 (Institute for Water Resources, 2000).

With the recent entry into force of the Kyoto Protocol, the CDM will soon begin operating.[7] In simple terms, the CDM allows developed countries to purchase greenhouse gas reduction credits from developing countries who have instituted land use changes that increase sequestration of carbon (such as reforestation and afforestation). The CDM rules are still being negotiated, but it has the potential to dwarf all mitigation markets to date.

B2B markets are closest to what we think of as functioning markets, where private buyers and sellers come together to exchange payments for services out of pure self-interest, with no major role for the government beyond enforcing contracts. The best example of such a market is the case of Perrier Vittel, the largest bottler of mineral water in the world.[8] In the early 1990s, seeking to reduce the nitrates and pesticides entering the springs around its bottling operations in north-eastern France, Perrier Vittel employed a range of payment mechanisms to change land used in the catchment area. For an estimated US$9 million, Perrier Vittel paid above-market prices to purchase 1500 hectares around its water springs. In an innovative move, Perrier Vittel then offered to give back free rights to farm the land to the prior owners if they followed prescribed management practices that minimised the risk of polluting the springs. Perrier Vittel also signed long-term (18–30 years) contracts with 40 farmers covering an additional

10,000 hectares, paying them to use less intensive dairy farming techniques.[9] The net result of these initiatives has been a reduction in non-point source pollution and significant changes in local dairy farming and animal waste management practices while eliminating corn cultivation and the use of agricultural chemicals.

There are, however, few examples of B2B service markets. The reason for this paucity lies in both the public goods nature of ecosystem services and the related difficulty of finding buyers. Markets for services can only be established if there are discrete groups of providers and beneficiaries, otherwise, transaction costs become too high for contract formation. The public goods nature of many services makes this a real concern. Biodiversity, for example, benefits agriculture through the insurance service of genetic diversity and benefits pharmacology through provision of antibiotics and other medicinal compounds.[10] The problem is that we *all* gain from these benefits, yet there is no sufficiently discrete class of beneficiaries that landholders can negotiate with, and the transaction costs of gathering enough beneficiaries together to negotiate for the service are too high. Thus, it is no surprise that private purchasers of biodiversity's benefits are hard to come by, which explains why there are so few B2B markets for biodiversity. Suppose, if a land use provides valuable ecosystem services but they are widely enjoyed by diffuse beneficiaries, in the absence of government intervention it is unlikely a market for services will arise.

As a result, most operating service markets are neither B2B nor mitigation markets, but *government payment schemes*. The best-known case of any service market, for example, is the New York City drinking water story. In the early 1990s, a combination of federal regulation and cost realities drove New York City to reconsider its water supply strategy. New York City's water system provides about 1.5 billion tons of drinking water to almost nine million New Yorkers every day (Goldstein and Izeman, 1990). Ninety percent of the water is drawn from the Catskill/Delaware watershed, which extends 125 miles north and west of the city (New York City Independent Budget Office, 2000). Under amendments to the federal Safe Drinking Water Act, municipal and other water suppliers were required to filter their surface water supplies unless they could demonstrate that they had taken other steps, including watershed protection measures that protect their customers from harmful water contamination.[11]

Presented with a choice between provision of clean water through building a filtration plant or managing the watershed, New York City easily concluded that the latter was more cost effective. It was estimated that a filtration plant would cost between $6 billion and $8 billion to build (Gretchen Daily and Katherine Ellison, 2004a). By contrast, watershed protection efforts, which would include not only the acquisition of critical watershed lands but also a variety of other programs designed to reduce contamination sources in the watershed, would cost only about $1.5 billion (Gretchen Daily and Katherine Ellison, 2004b). Acting on behalf of the beneficiaries of the Catskills' water purification services, New York City chose to invest in natural rather than built capital. Nor is New York City alone. As of 1996, the EPA indicated that over 140 municipalities qualified to use watershed conservation as a means of ensuring high drinking water quality (The Trust for Public Land, 1998b).

Similar markets may be found all over the world. In Australia, the state of Victoria's Department of Natural Resources and Environment has developed a program, known as Bushtender, to conserve native vegetation remnants on private property (Stoneham et al., 2002a). In exchange for payments from the state government, the landholders commit to fencing off and managing an agreed amount of their native vegetation for a set period of

time (Stoneham et al., 2002b). The program is based on the model of the Conservation Reserve Program (CRP) in the USA, the largest ecosystem service payment scheme in the world (Farm Service Agency). CRP provides annual rental payments and shares the cost of conservation practices on farmland.

In 1997, Costa Rica launched a nationwide scheme of payments for the provision of ecosystem services, known as Pagos por Servicios Ambientales (PSA) (Farm Service Agency). The PSA permits the government to enter into binding contracts with landowners for the provision of four services: sequestration of carbon, water quality and quantity (i.e. for drinking, irrigation or hydroelectric power), biodiversity conservation and aesthetic beauty for ecotourism (Farm Service Agency). By the middle of 2000, roughly 200,000 hectares of forest were being managed for service provision in exchange for payments. An additional 800,000 hectares had been proposed for conservation management but not included in the program because of inadequate funding. It is important to note, however, that most of the land has been managed for biodiversity, not water services. This is due primarily to the available resources and numbers of willing buyers. The World Bank, with a $32 million loan and the Global Environment Facility, with an $8 million grant, have provided the means to pay for biodiversity conservation. So far, the payments for water quality have come primarily from hydroelectric power generators concerned over sedimentation. Deforestation can lead to serious erosion particularly on hillsides. Forest cover prevents the rush of sediment loads into streams and, eventually, dammed reservoirs, which results in much lower maintenance costs for hydroelectric power plants that would otherwise have to dredge. There have been no contracts to date from water suppliers.[12]

The two things all these markets share in common are (1) the central role of government payments and, as a result, (2) the fact that there is only one buyer. Suppose, to overcome the collective action and public goods problems that hinder B2B markets, most successful service markets to date operate as *monopsonies*, with a dominant buyer for multiple service provider sellers. The only reason why biodiversity conservation contracts were so successful in Costa Rica was because of the unusual role played by the World Bank and the Global Environment Facility as a single, surrogate purchaser who stepped in with millions of dollars to purchase services on behalf of the world. The success of BushTender was also due to it being a monopsony.

Monopsonies have also arisen to create successful markets for other types of ecosystem services. In the Catskills, there was only a single purchaser for water purification: New York City's water authority. Whether for biodiversity or clean water, the government pays for these services on behalf of the citizenry. Such actions are entirely appropriate, it should be noted, since they correct the market failure posed by public goods. Nor, it should be noted, are monopsony buyers limited to governments alone. In Costa Rica, every water quality contract to date has involved a single dominant water user in the watershed (i.e. hydroelectric power producers concerned over sedimentation in their dams).[13] One might argue that water utilities and energy companies operate in a quasi-governmental capacity, but purely private markets often act as monopsonies as well. Thus, the case of Perrier Vittel is not only a B2B market but also a case of a dominant buyer and multiple sellers.

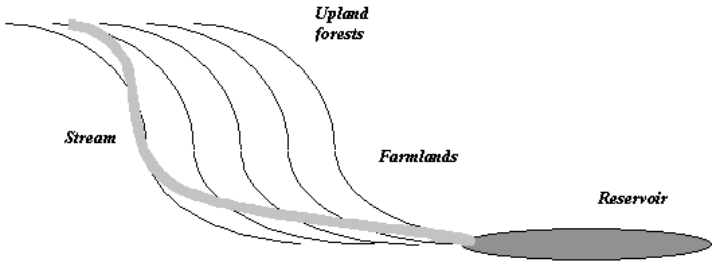
Because most service markets function as monopsonies, these effectively take the form of a *payment scheme*. But payment schemes for ecosystem services, indeed for any services, raise difficult issues that need to be confronted. There are good reasons, after all, that 'payments' and 'subsidies' are four-letter words to many economists. Indeed,

payment schemes can lead to what some might view as quite disturbing policy implications: Are we paying the right people? Are we sending messages that encourage or undermine an ethic of land stewardship? Are we effectively paying for rights that landowners never had?

The rest of this essay explores these difficult issues, addressing in turn the problems incurred through violating the polluter pays principle, the perverse incentives created by subsidies and their expressive consequences. Each criticism, while valid in theory, proves to be less problematic in practice for many services.

To ground our discussion, consider the following example in Figure 1 below (Heal et al., 2001). Imagine that the municipal water supplier owns the upland forest, which naturally filters and cleans water as it flows through the upper watershed. Property owners in the farmlands are dairy farmers, grazing cows on their fields beside the stream that flows into the reservoir. The farmers could manage their land to provide an improved service of water purification by planting riparian vegetation buffers (i.e. erecting fences to protect strips of plants alongside the stream from grazing). Such vegetative buffers capture nutrients and reduce silt before they reach the watercourse. Water consumers downstream benefit from these actions when drinking clean water that does not require extensive pretreatment. Farmers might benefit from reduced streambank erosion.

Figure 1 Water flow through a watershed



Traditionally, this would be the end of the story. No benefits would be produced for few land owners *actually would* plant riparian buffers. Farmers may well have been informed of the benefits of this practice for themselves and for downstream users, but it is unlikely that they would change their behaviour because of the hassle and cost of fencing and the concerns over the loss of productivity from setting aside pasture. And those who did fence off their streams would bear all the costs, with no contributions from those downstream who benefit from the positive externalities of cleaner water. Enter ecosystem payments, however, and the farmers now have an incentive to put in riparian fencing. Sounds great.

If one enquires more closely, though, paying for services suggests a tension. Those farmers who have already put in riparian fencing no longer have a significant potential for increased service provision and as a result, are unlikely to be paid. Should every landholder who provides environmental services be paid? Given a finite budget, the answer to this would seemingly have to be ‘no’. It is hard to imagine a practical scheme, for example, that pays everyone whose vegetation reduces nutrient flow in the watershed.

If one seeks to pay for discrete cases of ecosystem service provision, clearly some land uses are more important than others. But how should one decide who gets paid and who does not?

In the case of Costa Rica, landholders are being paid to keep their lands forested – these are conservation payments *not* to change the land use, and instead to maintain current practices. In the case of New York City, payments are made both for maintaining the status quo and in some cases, for changing land use practice. In significant contrast to the Costa Rican example, though, some of those being paid in many respects also are *causing* the problems. For example, because some dairy farmers have not built sufficient infrastructure or established riparian vegetation, their cows are discharging significant nutrient loads into streams.

Which landholders should be supported by ecosystem service payments – those who currently provide services or those whose properties pose the greatest nutrient or sediment problems (and hence the greatest potential for increased service provision)? This decision will be a challenge for many service markets. To frame this dilemma more starkly, imagine two adjacent farmers, A and B, who raise cows for a dairy operation on gently rolling land beside a stream that flows into a reservoir. Concerned over streambank erosion, five years ago Farmer A constructed fencing alongside her streams, creating a ten-foot riparian buffer on either side of the bank. This change in land management has significantly reduced the amount of nutrients and soil washing off her land and consequently, has reduced the eutrophication and turbidity downstream. Farmer B, by contrast, has continued to manage her land much the same way as her predecessors, with nutrient and soil run-off after large storm events affecting water quality in the downstream reservoir. Should the water supplier be willing to make ecosystem service payments to address eutrophication and turbidity control? If so, which farmer should receive payments, and how much?

Posing these questions more fundamentally, what is the proper paradigm for ecosystem service provision by farmers? Should we think of farmers as polluters, and therefore subject to the polluter pays principle, the touchstone for much of modern environmental policy? If so, they presumably should not be paid, but regulated or taxed instead. Or, by contrast, are farmers potential providers of valuable services who are as deserving of payments as water treatment plant operators?

To demonstrate this in an absurd example, one might argue that farmers should not be paid to reduce their water pollution any more than I should be paid to stop mugging people.[14] But is this an apt analogy? This sounds absurd only because I clearly do not already have the right to assault. My duty of care in this case is clear – I have no entitlement that I can exchange for payment because criminal sanctions already prevent me from robbing people. But is the duty of care sufficiently strict and clear in the land management context such that paying farmers not to allow manure and soil into watercourses sounds equally absurd? At least at the moment in the USA and Australia, the answer is 'probably not'. Otherwise, payments would seem ridiculous because regulations already made riparian fencing and grass swales mandatory.

In evaluating the relative merits of this argument, it is helpful to consider whether it makes sense in any other setting. Take a step back, for example, and consider this in the pollution context. What would your immediate reaction be to a proposal that we should pay a factory to stop polluting because we all benefit from clean air? Sounds silly, right? But are farmers any different, in that the service they provide by putting in riparian fencing is really little more than reducing the contribution of their cows to eutrophication

downstream? This turns out to be a less than compelling argument because, as noted above, payments to the factory only seem silly because the duty of care for factory pollution has clearly been established. Pollution laws already limit emissions. As a result, if we want them to improve upon the current standard to obtain even cleaner air, we essentially *do* pay them. In the US EPA's regulatory innovation program during the Clinton Administration, known as Project XL, the agency promised greater flexibility (an administrative law payment of sorts) in exchange for superior performance (US Environmental Protection Agency). And trading schemes under the Clean Air Act provide a similar lesson.[15] When initial sulphur dioxide permits are distributed based on historical emissions rather than auctioned off, existing plant owners are effectively allocated permits to pollute. Companies that emit less than permitted are rewarded by being allowed to sell their excess allowances to other sources. In practice, then, payment schemes operate under the *polluted* pays principle, and that may not be a bad thing.

The next major concern raised against payments for ecosystem services is that they operate as subsidies. While common in public policy, subsidies and payment programs raise all sorts of red flags for policy analysts. These criticisms can be grouped into three broad categories: payments are inefficient because of holdouts and free riders, payments lead to rent-seeking and the diversion of funds from more socially worthwhile causes and payments create moral hazards that encourage undesirable behaviour. The relevance of these concerns varies a great deal depending on the service in question.

The problems of *holdouts and free riders* are most easily seen in the context of biodiversity conservation. The functional value of a reserve design or wildlife corridor depends critically on contiguous parcels. If successful, the benefits from the sum of connected land parcels managed for biodiversity conservation should be greater than its parts. This can be frustrated, though, by the actions of a very small number of landholders who can hold out for prices well above market rates. Without their participation, it may be impossible to create effective habitats. Moreover, neighbours of those who dedicate their lands to biodiversity conservation may choose not to conserve biodiversity on their own land but, instead, free ride on the wildlife amenities on adjacent land. Given these two obstacles to competitive markets, one can understand the calls for coercive instruments. It remains an important and unresolved empirical question, however, whether these theoretical problems are important in practice. After all, there has been a boom in land trusts since 1990s.[16]

Holdouts and free riders are likely much less of a concern in the context of water purification services because the effectiveness of landscape management, for example, is less likely to turn on the actions of a handful of landholders. To guard against holdouts, BushTender and the CRP rely on reverse auctions – where farmers bid against one another to provide the *lowest price* for the government to choose. So long as the reverse auction is competitive and there are a sufficient number of farmers involved, holdouts and collusion become less likely.

If payments are a one-off exercise, the analysis is fairly straightforward. However, one must keep in mind that the relative advantages of policy instruments shift depending on the time period. In other words, if payment schemes prove successful in providing services efficiently, one might expect that payments could become a regular process. But if so, then the issues raised by a payment scheme change significantly over the longer term, implicating problems of rent seeking, moral hazard, price equilibrium and norm shaping. If payments continue into the future, for example, then collusion becomes more likely.

The possibility of repeat players recasts the problem of holdouts in the guise of extortion. For instance, a landholder who had signed a ten-year contract for a particular land management regime might compete for a new contract. Consider, for example, a barely concealed threat along the lines of, 'Now that the first ten years have passed, I'd like payments for another ten years (at a premium of twenty percent to take inflation into account, of course) or else I may have my cows start visiting the streams again'. In the context of water quality, without payments how likely is it that a farmer will change her land use in a manner that degrades water quality, perhaps removing the fencing and swales?

In theory, repeat payments for water purification services need not be expensive. If most of the payment covers capital costs, then after the initial payment the farmer will be providing more services than before and, when the next round of payments occurs, will likely get no more than maintenance payments, since there will be other bidders offering greater potential increases in service provision. There may be an argument to pay more than maintenance costs if there is a credible risk of losing service provision. Such payments would act as a type of insurance premium. Even with such payments, however, some farmers may be tempted to hold out for still higher payments.

The likelihood of holdouts who have already received payments will depend in large part upon three considerations: the competitive dynamic among the landholders, the landholder's contribution to upfront costs and the size of future opportunity costs. If the landholder contributed significantly to the costs of putting in swales or fencing, for example, then taking them out will be less likely. Indeed, in economic terms, the land management should only change when the profits from new land uses outweigh both the current income and the land management transition costs. And even if the farmer did not pay for the initial capital costs, she may well now regard the fencing and swales as an asset, adding value to her farm.

It turns out that the threat of holdouts is much more significant in the context of biodiversity than in water quality. If a farmer is paid to fence off a stretch of native vegetation and, when payments cease, allows her cattle to roam through and graze, then most of the benefits of biodiversity conservation may be lost, as the available habitat for an endangered population becomes scarcer and extortion becomes more likely. With water quality, in contrast, the benefits from the service of water purification have been enjoyed throughout the contract, and if the services are not received from one farm, hopefully, a comparable level of service or better can be received from another. Moreover, changing the land use to discourage biodiversity (such as mowing the lawn) imposes fewer costs on the farmer than removing riparian fencing that may lead to soil loss from erosion or loss of stream banks.

Repeated payments also raise the problem of *rent-seeking*. Whenever public funds are made available, one can expect potential beneficiaries to channel the funds to themselves and to increase funding. The CRP, for example, which was launched as a short-term program to promote better stewardship of erodible lands, is now a huge, stable $1.6 billion annual farm subsidy. Efforts to closely tailor its implementation seem to have been frustrated largely in practice in order to ensure broader participation. The history of the Agricultural Conservation Program is also a case study in how well-intentioned programs can be overtaken by local political interests.[17] Even if a payment scheme were established that created a competitive dynamic among farmers to provide services at least cost, there is a very real possibility that, over time, this could follow the path of the CRP and transform into a blunt subsidy.[18]

The final major concern over payments is one of moral hazard. Returning to our Farmer A and Farmer B example, recall that Farmer A carefully managed her land, putting in riparian fencing on her own initiative to prevent streambank erosion, while Farmer B followed traditional practices, allowing her cows to graze in the stream and not putting in fencing. At first glance, paying Farmer B to improve her property through riparian fencing makes good sense. This will reduce pollution loading in the reservoir. But, how can this be described as an ecosystem services payment scheme? On its face, this seems to be paying more for the *lack* of ecosystem services. That is, Farmer A is already providing services but will receive less than Farmer B, who currently provides few. The key point to recognise is that we are not really paying for ecosystem services but, rather, for *improvements in service provision*.

Our goal, after all, is improved water quality. In that respect, we should value most of those actions that improve the water quality on the margins, and those will primarily be actions taken from today that improve the status quo. Through this view, then, we should pay more initially to the Farmer B's of the world who change their land use than to the Farmer A's who have already made the improvements, for the simple reason that the actions of Farmer B will lead to greater marginal improvements.

This approach, however, may pose a problem known as a 'moral hazard'. If we say people are being paid to provide a service, then how can we ignore those who already provide it? What kind of message does that send? Are we not essentially paying off the bad actors and thereby encouraging undesirable behaviour? More generally, how do we equitably account for the baseline that is already out there? Those farmers who have already made the investments and managed their land responsibly may not receive any payments. Only those who have been less responsible will benefit, the argument goes, creating a disincentive to land stewardship. As critics of the CRP program have made clear, responsible land managers can become dispirited if those who employ less responsible land management practices effectively are paid for doing so. This surely is not conducive to the kind of land management ethic we are trying to encourage.

These are not easy challenges to answer. One response, though not entirely satisfying, is simply that life's not fair. Governments subsidise some agricultural activities more than others all of the time. Sugar cane growers in Florida may receive more federal money than grain farmers in South Dakota; peanut growers in Georgia may receive more advice from extension services than apple growers in Washington. Moreover, neither subsidy politics nor markets are based on equity. Markets are designed to exploit differences among buyers and sellers, not remove them. A market that seeks to eliminate heterogeneity will be a flat market.

Nor do all landholders need to be paid. If land care preferences follow a normal distribution, at one end will be those who refuse to alter their land management practices unless forced to do so. They are balanced at the other extreme by those who are willing to manage their land in an environmentally sensitive manner, with or without government intervention. They do not need payments as an inducement. The Nature Conservancy and Greening Australia, for example, work with many landholders who are willing to pay the legal fees to place conservation easements on their properties.[19] Those between the extremes, willing to change their land uses to provide services but concerned about the costs involved, are the prime target audience for a service payment scheme, not those who have already incorporated a stewardship management ethic.

Nonetheless, there is a likelihood of unnecessary payments. In other words, a payment scheme will attract bids not only from those who are willing to change their

land management practices because of the payments, but also from those who would have made the changes in any case, but appreciate a handout when they can get one. However, this problem of 'consumer surplus' may not be very large in practice, because presumably most people who would change land management on their own have already done so. The use of a reverse auction, as in BushTender, will also reduce the cost of these payments, because these farmers' bid prices should be quite low (in the sense that they would have done it for free, but some payment is better than none).

These points address issues of equity, though, not of perverse incentives. Of possibly greater concern is the likelihood that the Farmer B's of the world will delay improving their land management practices in the expectation that they will eventually be paid to do so. As noted in the earlier discussion of extortion, paying farmers for biodiversity conservation has been criticised by some as tantamount to granting landholders an implicit right to hold the environment ransom (Young et al., 2003a). In the extreme, one might imagine farmers actively *worsening* their land management practices to increase payments for their potential service provision.

To place this in a more domestic setting, imagine that your condo association wants to address the problem of noisy parties by having the loud apartment owners place a restrictive covenant in their leases (Wiener, 1999). Would offering payment to the noisy neighbours in exchange for restrictive covenants be a good solution? Not if it created a perverse incentive for other neighbours to start cranking up their stereos so they also could be bought off or, worse yet, if word got around and heavy metal fans moved into the building expressly so they could be paid to use headphones. Indeed, a standard economic criticism of subsidies is that they can unwittingly reward the very behaviour they are trying to suppress.[20]

While theoretically and intuitively an obvious problem, how serious a concern should this be in the field? We have a good understanding of how to address moral hazards that arise under the polluter pays principle (i.e. victims inviting the harm),[21] but in the service payment scheme such approaches are not easily applicable. Nonetheless, in the context of ecosystem services, moral hazard concerns do not seem worrisome unless the expected private benefits of poor land management exceed the costs. Actively encouraging erosion of the topsoil or stream banks on your farm is far different than cranking up Aerosmith after 10 PM or increasing production at a polluting factory. Increasing your attractiveness for potential service payments, can carry a significant cost in long-term farm productivity. Such a strategy also carries a significant risk if payments are granted on a competitive basis, since some farmers may receive no funds for running down their land. After all, given the likely budgets for payments, it is probable that less funding will be available than the potential recipients request. Both BushTender and the Costa Rican programs, for example, were oversubscribed.[22] In total, if the relative value of payments is low compared to losses from strategic behaviour, then moral hazards are less likely a problem.

Once one moves away from moral hazard actions that impose costs, however, the problem becomes more difficult, as in the case of biodiversity conservation. There may be little direct cost in switching to crops or field management that degrade critical habitat, and moral hazard concerns cannot be as easily dismissed.

A related concern over creating markets for ecosystem services centres on the impact this might have on the public's norms toward land stewardship. Do public payments for service provision send the message that private provision is unnecessary or not valued? Government payment programs may risk undermining the land ethic by commodifying

environmental stewardship, making responsible land management turn on money instead of fundamental values.

Mike Young, Tian Shi and Jim Crosthwaite have raised similar concerns in assessing markets for services in Australia. Once payments become commonplace, they charge, this risks eroding common notions of an environmental duty of care and discouraging private investment in the environment by creating the impression that environmental stewardship is the duty of governments rather than individuals (Young et al., 2003b).

These are difficult concerns to address. Laws clearly can influence norm formation. As Carol Rose has explained, "our laws are not just our controllers, but our teachers. For better or worse, normative or hortatory lessons are embedded in our laws, and we need to think about the education they impart when we adopt legal institutions to manage resources…." (Rose, 1991). But *how* norms change and influence behaviour is a complicated process. Indeed, all instruments have normative objections. Regulations can be seen as denigrating private ordering and, in turn, can lead to private resistance. Markets and taxes, by contrast, have negative connotations of commodification and abdication of governmental control. Nor do empirical studies provide clear direction on the messages policy instruments send and their impacts on social learning.[23] The role of service markets in norm transformation is simply not known. It is worth considering, though, why payments should be any more harmful to development of a land ethic than regulations or taxes directed at the same policy goal. Regulations and taxes certainly have not created an enduring land ethic to date. To the contrary, one can imagine how a transformation of farm commerce from growing crops to growing services truly would inspire a different vision of the land.

2 Conclusion

This is an exciting time to be working in the field of ecosystem service markets. Governments at the local, national and international levels are increasingly aware of the potential for service markets, as are scholars. As the number of local service payment schemes grow, however, serious attention needs to be paid to the potential downsides of such payments. This essay has identified the major concerns raised by payments and suggested some ways to overcome or reduce their impacts. Payments hold great promise. Wisely structured, their perils can be minimised. In the final analysis, though, it bears keeping in mind the limits of any payment scheme, no matter how well constructed. In this regard, it is helpful to consider the thoughts of Aldo Leopold: the famed ecologist and the most influential American writer on conservation. While Leopold would have welcomed the commitment of funds for conservation payments, John Echeverria notes, he thought the 'fallacious doctrine that government must subsidise all conservation' would ultimately 'bankrupt either the treasury, the land, or both'. Public ownership 'can cover only a fraction of what needs to be done, and then only awkwardly, expensively and with frequent clashes of interest'.

At the end of the day, he thought that those concerned about the problem of maintaining the health of the land had to grapple with the reality of private land ownership. 'The basic problem is to induce the private landowner to conserve on his own land, and no conceivable millions or billions for land purchase can alter that fact, or the fact that so far he hasn't done it' (Echeverria, 2000).

There is enormous potential for increased payments for ecosystem services, but they can only get us so far.

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Notes

[1]Degraded ecosystem services contribute to many natural disasters. Indeed many commentators have argued that the devastation of the recent tsunami in southeast Asia was worsened by the destruction of mangroves for coastal development. The net effect of this coastal development was weakened ecosystem services of flood and storm buffers. *See, for example*, Earth Island Institute, *Loss of Mangrove Forests Contributed to Greater Impact of Tsunamis*! Available at: http://www.earthisland.org/map/tsunami.htm#1. Consider, as well, in the quote below, the importance of water retention and purification provided by forests.

> Widespread flooding in China's Yangtze River Basin in … 1998 left over 3000 people dead, hundreds of thousands homeless and destroyed billions of dollars worth of property. Rapid siltation in hydropower reservoirs in Malawi threatens the future supply of electricity and poor water quality pushes up turbine maintenance costs to unsustainable levels.… In a world where one-fifth of the population lacks access to safe and affordable drinking water and half the population lacks access to sanitation, improving our understanding of how markets for forest watershed protection may improve water quality and augment dry season flows is critical.
>
> Natasha Landell-Mills & Ina T. Porras, Int'l Inst. for env't & dev., silver bullet or fools' gold? A global review of markets for forest environmental services and their impact on the poor 111 (2002) [hereinafter Silver Bullet]. Available at: http://www.iied.org/docs/flu/psf_silvbullet. pdf.

[2]A NEXIS combined newspaper search for 'Ecosystem service!' for example, reveals a steady increase in citations over time – 14 cites in 1996, 69 in 1998, 106 in 2000 and 146 in 2002.

[3]Silver Bullet, *supra note* 6, at 3.

[4]The Katoomba Group's Ecosystem Marketplace. Available at: http:// www. ecosystemmarketplace.com/ (last visited 18 February 2005). The author of this Article serves on the Katoomba Group's Ecosystem Marketplace Advisory Board. Michael Jenkins, the president of the nonprofit organisation Forest Trends, described the website as a 'Bloomberg meets Google meets CNN' for the emerging environmental services market. *World's First Multi-Billion Dollar Green Marketplace Opens*, Asia Pulse, 12 October 2004, LEXIS, News Library, Asia Pulse File.

[5]Clean Water Act, 33 U.S.C. § 1311(a) (2000). Section 301 of the CWA prohibits 'The discharge of any pollutant by any person' into navigable waters. *Id*. §1311 (2000).

[6]Section 404 authorises the Secretary of the Army to 'Issue permits, after notice and opportunity for public hearings for the discharge of dredged or fill material into the navigable waters at specified disposal sites'. 33 U.S.C. §1344(a) (2000).

[7]The Kyoto Protocol entered into force on 16 February 2005. Protocol to the United Nations Framework Convention on Climate Change (Kyoto), 11 December 1997, 16 February 2005, 36 ILM 1454 (1997). Even without the Kyoto Protocol in force, there were over $300 million in carbon trades in 2002. Interview with Adam Davis, Peregrine Consulting, Wash., D.C. (30 October 2003). This figure includes payments for both carbon sinks (e.g. paying for reforestation and afforestation) and carbon reductions (e.g. reducing emissions through technology improvements).

[8]Maritta Koch-Weser & Walter Kahlenborn, Bishkek Global Mountain Summit 2002, Legal, Economic, and Compensation Mechanisms in Support of Sustainable Mountain Development §2.5. Available at: http://www.mtnforum.org/resources/library/kochx02a.htm.

[9]The payments are intended to cover opportunity costs and average US$230/hectare per year for seven years (an investment of about US$155,000 per farm). Perrier Vittel has also provided farmers free technical support and paid for farm infrastructure (primarily buildings and machinery). The company retains ownership and has the right to monitor their proper use. *Id*.

[10]Roughly one in four pharmaceuticals are derived from plant sources and another one in four from animals and microorganisms. *See* Norman Myers, *Biodiversity's Genetic Library*, *in* Nature's Services, *supra note* xx, at 259, 263.

[11]Safe Drinking Water Act, 42 U.S.C. §§300g-1(b)(7)(C) (2000).

[12]Another Costa Rican initiative worth noting is similar to the Catskills case. Costa Rica's Ministry of Environment and Energy charges 20,000 water consumers near San José a small surcharge on monthly water bills. The funds are used to pay upper watershed farmers who have agreed to conserve and manage their forests. Daily & Ellison, *supra note* 26, at 65.

[13]Pagiola, *supra note* 10, at 49.

[14]Interview with Mike Young, Division Chief, CSIRO, Adelaide, Australia.

[15]Clean Air Act, 42 U.S.C. §7651 et. seq. (2000).

[16]There were over 1200 land trusts in the USA in operation by the end of 2000, with nearly 65% of those having been created since 1981. These trusts permanently protect nearly 6.5 million acres of land. Roughly 40% of this land is protected by the over 11,670 conservation easements deeded by private landowners to local, state and regional land trusts. Nancy A. McLaughlin, *The Role of Land Trusts in Biodiversity Conservation on Private Lands*, 38 Idaho L. Rev. 453, 454 (2002). The success of the land trust movement does not, of course, prove that holdouts are not an important or common occurrence – just that they are not sufficiently significant to block payments and markets. As Chris Elmendorf, who worked on conservation easements and real estate transactions in practice, notes, such concerns are very much on the minds of people trying to bring these deals to fruition. 'I can attest that the basic attitude of many practitioners to the holdout problem is "hope against hope"'. Interview with Chris Elmendorf, Professor, UC Davis Law School (1 October 2003).

[17]Agricultural Conservation Program Objective, 7 C.F.R. § 701.3 (2004). Christopher Elmendorf, *Ideas, Incentives, Gifts, And Governance: Toward Conservation Stewardship Of Private Land, In Cultural And Psychological Perspective* 2003 U. Ill. L. Rev. 423, 497 (2003) (describing how, in Agricultural Conservation Program, 'Congress overrode the USDA and forced it to subsidize whatever practices the local "county committees" wanted subsidized').

[18]A study of farmer irrigators in Arizona provides an interesting insight into the farmer–government political dynamic. The researcher, Helen Ingram, was trying to figure out why farmers were supporting a water project that would charge more per acre foot than they could afford. Why would rational economic actors support a water project they could not afford to use? Ingram found that support for the project was, on its face, economically irrational because the projected water costs were greater than the farmers' willingness to pay.

Instead, farmers made a political judgement, deciding on what Ingram termed their 'willingness to play'. If they could get the government to build the project, farmers reasoned, the government would bail them out if it proved too expensive and would provide a subsidised supply. As Joseph Sax describes,

> "farmers were willing to "play" the game of politics, and to bet that the rules of the game could change. In fact, a long history of western water projects gave credence to the farmers' tactic: in decade after decade, the government had effectively forgiven agricultural debts on projects that legally required repayment".

Sax, J.L. (1991) *The Fate of Wetlands in the Face of Rising Sea Levels: A Strategic Proposal*, 9 UCLA Journal of Environmental Law and Policy, Vol. 143, pp.149–150. Citing research done by Ingram H., Martin, W.E. and Laney, N.K. (1982) 'A willingness to play: analysis of water resources development' in Arizona, in 2 Water and Agriculture in the Western U.S. Part V (G. Weatherford ed., 1982).

[19]Interview with Carl Binning, Director, Greening Australia, Canberra, Australia (23 March 2003).

[20]In their well-known book on environmental economics, for example, Baumol and Oates set out an economic proof showing that subsidies given to a polluting industry are counterproductive.

> "[A]lthough a subsidy program may reduce the emissions of each firm by itself, the subsidies, far from yielding a reduction in total industry emissions like a pollution tax, may, in fact, increase emissions from their unregulated level! … In a competitive industry, where polluting emissions are a fixed and rising function of the level of industry output, equal tax and subsidy rates will normally *not* lead to the same output levels or to the same reductions in total industry emissions. Other things being equal, the subsidy will yield an output and emission level not only greater than those that would occur under the tax, but greater even than they would be in the absence of either tax or subsidy".

Baumol, W.J. and Oates W.E. (1998) *The Theory of Environmental Policy,* 2nd edition, pp.221–222.

[21]One can require the polluter to pay the state rather than the victim, or reduce compensation through doctrines such as mitigation of damage or contributory negligence. *See* Wiener, *Global Environmental Regulation*, *supra note* 45, at 771.

[22]The CRP guards against the moral hazard problem by requiring that the farmland be cultivated in four of the past six years. To guard against providing an incentive for poor management (i.e. worse than the status quo), one could also condition eligibility for payment on a variant of the neutral or beneficial effects test – recent evidence of land management that has not degraded water quality.

[23]In studying problems of collective action and the NIMBY phenomenon, Daniel Kahan has reviewed payment schemes that reward communities in exchange for siting noxious facilities. He has found that such compensation-based siting policies, though lauded as clever alternatives to mandated siting decisions, were a major disappointment. Communities continued to oppose proposed sitings, regardless of revenue sharing offers. Indeed, there is evidence that compensation schemes sometimes make the NIMBY problem *worse*. According to some studies, residents often bridle at 'compensation offers … as attempts to buy them off or bribe them.' … It would be a mistake, however, to conclude that compensation schemes *never* work. At least some opinion studies have shown that offers of compensation can significantly increase willingness to accept the siting of a noxious facility. Moreover, compensation in one form or another *has* nearly always been a part of the successful waste-facility siting efforts in the United States and Canada in recent decades.

Khan, D.M. (2003) 'The logic of reciprocity: trust, collective action, and law', *Michigan Law Review*, Vol. 102, pp.71 and 86–87.

The value of everything

Stuart L. Pimm

Economists and ecologists have joined forces to estimate the annual value of the services that Earth's ecosystems provide. Most services lie outside the market and are hard to calculate, yet minimum estimates equal or exceed global gross national product.

Economists' self-effacing definition of their craft is that it is one that knows the price of everything and the value of nothing. In that lies a crucial distinction.

Market prices are the easier objects of study, recorded abundantly in units (currencies) with known, if varying, calibrations. Values are more slippery, being likely to vary widely from person to person and from generation to generation. Prices, moreover, reflect incremental (or 'marginal') costs. Diamonds trade for a higher price than does fresh water. Yet the value of all fresh water is infinite: we could not survive without it. For ecologists, prices are woefully incomplete measures of nature's value that poorly prefigure the consequences of humanity's exponential growth. For economists, the challenge is how to assess an ecosystem's non-market values and predict their future trends. The words 'economics' and 'ecology' share a common root, yet for many years their practitioners had little to do with each other.

A turning point may have been C. W. Clark's 1973 demonstration that the most profitable strategy for harvesting whales is to convert all of them quickly into money in the bank[1]. Even the most stingy savings account produces interest income faster than whales reproduce themselves. Using the mutually intelligible medium of mathematical models, Clark's economics explained ecological history. Maximizing profits demanded that the slow-moving, inshore-feeding species were first hunted to extinction, before whalers tackled species whose capture required more advanced technology. The appropriately named right whales did go first, the 'wrong' whales following at ever shorter intervals. Generally, only species that grow faster than money in the bank should be harvested sustainably.

But if whales are more than just meat, how are we to estimate these other values? Trees in tropical forests grow slowly too: must economics doom them to extinction in the next century, like some whales in the last? On page 253 of this issue[2], a team of ecologists and economists, sponsored by the newly established National Center for Ecological Analysis and Synthesis in Santa Barbara, California, address such questions. Costanza *et al.*[2] take the flippant definition of economics to heart, estimating the annual value of all the world's ecosystems — essentially, the value of everything.

Take whales as an example. Whalers once set out from Lahaina and Nantucket on year-long trips armed with harpoons. Better-paid descendants set out on day-trips, escorting passengers armed with cameras. The cultural value of whales far exceeds that derived from their meat or oil, even if one only counts the price paid for boat tickets. Whales also have ecological roles that maintain species abundances of other marine species, including commercially valuable fisheries. These values, too, could be very large, and easy to estimate in theory, if not in practice.

Estimating other values is more contentious. Many people would consider Baker and Palumbi's observation[3] of the presence in Japan's sashimi trade of meat from the long-protected humpback whale to be a violation not only of international laws, but of religious principles, or to be evidence of unacceptable cruelty. Economists incorporate these views by asking how much the public would pay to protect whales. (A real example of such calculations involved asking how much the public felt deprived when the oil from the *Exxon Valdez* gummed up Alaska's scenically spectacular shoreline.)

Herein lies a vigorous debate, for others deem such calculations irrelevant — a feeble, last gasp of economists to fix their inability to assess real values. But would anyone accept child labour just because willingness-to-pay estimates for its abolition were smaller than the money saved by paying children less than adults? Aren't there overarching moral issues in placing monetary values on a sustainable environment for future generations? Costanza *et al.* point out that moral arguments make the discussions more difficult, but go on to say that they have no choice but to try to take them into account. In practice, we do indeed make financial trade-offs involving moral dilemmas, and the authors recommend that we proceed with both moral arguments and economic assessments.

Ecologists must grapple with exceedingly complex ecological interactions. Clear-cut a forest and the price of adjacent homes will

Estimating the cultural value of the oceans

Costanza and colleagues' summary table, Table 2 (page 256), is both fascinating and frustrating. Some numbers are small, others are huge. For none of them is there an indication of how they are obtained. How could there be in a journal with strict space limits? *Nature*'s Web site http://www.nature.com provides a solution that until recently would have been impossible: it displays the six-page spreadsheet and accompanying 18 pages of footnotes to document the calculations.

For example, how do the authors obtain a value of $76 per hectare for the cultural value of the world's open oceans? Multiplied across the planet's oceans this is a huge number – roughly $2.8 trillion. The tangible economic evidence of valuing the sea is how much more we will pay for coastal real estate than for comparable properties inland. (The calculation for the cultural value of coastal waters themselves is separate, and takes into account such factors as the scientific value of estuaries.)

For California, the difference between coastal and inland real estate is $10 million per hectare, for Alabama, only $500,000. Costanza *et al.* estimate the length of the coastlines of wealthy and less developed nations to be 194,435 km and 284,795 km, respectively, and assume coastal properties extend 0.5 km inland. They further assume that wealthy nations value their coasts 100 times as much as poorer ones, making the latter's contribution relatively tiny.

The total values come to $5–105 trillion, using the Alabama and California estimates, respectively. Amortized over 20 years, this yields the average value of $2.8 trillion, or $76 for each of the oceans' 36.3 billion hectares. All that is before we've added the money spent on tall ships (and yachts), the sextants to sight the stars to steer them by, and all the other paraphernalia needed to mess about in boats. **S. L. P.**

drop. The nearby streams will fill with sediment and lose their fish. Flowing to the sea, the sediment may smother the coral reef offshore, destroying its fish, beautiful corals, and the obscure invertebrate containing clues to the cure for cancer. The forest is a carbon sink. Its loss may accelerate global warming and sea-level rises. The coral reef may provide inshore areas with protection against storms. Costanza and colleagues' approach to these diverse services is to group them into 17 categories (the value of gas regulation, then climate regulation, through to cultural value) and to classify the planet's surface into 16 subdivisions or biomes. Then they proceed to estimate the 272 combinations one at a time. A summary of their valuations appears as Table 2 on page 256 of this issue, a much more detailed version being available as Supplementary Information on *Nature*'s Web site (see box on the preceding page for details).

Many combinations have yet to be estimated. Mountains, the Arctic and deserts certainly have cultural values and devoted eco-tourists, but these are absent from the grand total of $33 trillion per year. Absent, too, are urban areas with city parks. A recent visit to New York's Central Park convinced me that children playing there appreciated its greenery, even if their parents living in the surrounding high-rise housing were too poor to own trees of their own. Filling in these and the other omissions will prove a rich training ground for graduate students in ecological economics.

Some of the numbers will be controversial. If the oceans were not there, re-creating their nutrient cycling would require removing the nutrients from the land's runoff and returning them. The estimate of this service's $17 trillion value is arrived at by multiplying the cost of removing phosphorus and nitrogen from a litre of waste water by the 40,000 cubic kilometres of water that flow from the land each year (see Web site). It is geological cycles that return these nutrients. In the short term, many would not notice (and perhaps not care) what happens to the elements as they flow into the ocean. Even without this service, the remaining ecosystem services total $16 trillion annually, a number to compare with the global GNP (gross national product) of $18 trillion.

Parallel arguments for freshwater ecosystems are more immediate. We use fresh water directly and the function of natural ecosystems in waste treatment is large and frequently overlooked. Here the ecologists' intuition that current prices are a poor predictor of future value is self-evident. The price of an essential resource such as water will rise nonlinearly as it becomes scarce. We already use half of the available global supply of fresh water[4]. In some places, the situation is critical. Israel already uses more water than is available, taking the remainder from aquifers under the occupied West Bank, and off watersheds in the Golan Heights and southern Lebanon[5]. The region's population is increasing rapidly and its peoples have aspirations for a better life. The nonlinearities in the value of ecosystem services have political as well as economic consequences.

Table 2 on page 256 informs a strategic debate about why we should protect ecosystems. A powerful argument is that we should protect biodiversity as a potential source of new medicines and genes for crop improvement. Costanza *et al.*, quoting as-yet unpublished work by D. Pimentel, show that cultural and recreational uses of nature are even more valuable. Pimentel estimates the value of over-the-counter, plant-based drugs at $84 billion annually, but eco-tourism at $500 billion.

The real power of Table 2 lies in its use for local decisions. For example, a proposed project in southwestern Brazil and adjacent countries would straighten and deepen the rivers and so drain many of the surrounding wetlands — the Pantanal. The value of the increased quantities of soybeans that will be marketed is a simple calculation, but a grossly incomplete evaluation of the project's consequences. The Pantanal is an area that provides unusually high ecosystem services. Even if all the globally averaged benefits do not apply to this particular region, the global accounting provides a checklist for those who make difficult local decisions. Increasingly, such decisions will be informed by those who realize that there is more to a whale than its meat, and that wetlands, like all other ecosystems, provide services we cannot afford to replicate. □

Stuart L. Pimm is in the Department of Ecology and Evolutionary Biology, The University of Tennessee, Knoxville, Tennessee 37996, USA.

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Geomorphology

When streams collide

Chris Paola

Dramatic effects can occur when two solid objects collide. The effects produced when two rivers collide are no less dramatic, but they are less familiar because they mostly happen under water.

The veil is lifted for one of the largest rivers in the world in the paper by Best and Ashworth on page 275 of this issue[1], which reports a sequence of bathymetric surveys in and around the confluence of the Jamuna and Ganges rivers in Bangladesh over a period of 28 months. They have discovered one of the mightiest natural scour holes ever described: about 30 m deep, some five times deeper than the channels feeding into it. Despite its great size, the scour is nimble: it migrated downstream at a mean rate of nearly 2 km per year over the measuring period.

There are several perspectives from which the size and dynamism of this impressive hole in the river bed are important. But first, why is the scour there, and how does it form[2–8]? Think of the confluence of two nearly parallel streams with different speeds. As the flows merge, the difference in speed gives rise to velocity shear and formation of the familiar line of vertical-axis vortices that one commonly sees in streams. In contrast, symmetrical confluences with more abrupt angles also produce vortices, but their axes are submerged and roughly flow-parallel (Fig. 1). So they are not obviously visible from the surface. The opposed components of momentum of the two colliding streams push the free surface of the water up in the neighbourhood of the junction and force a strong downwelling of water beneath the surface.

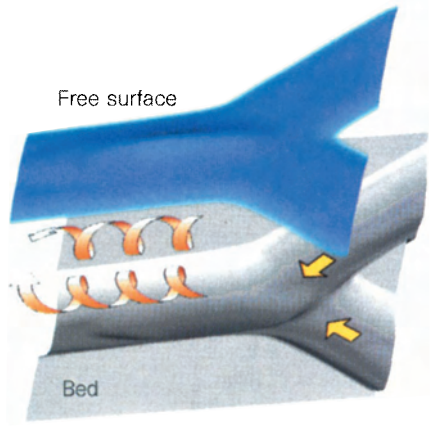

Figure 1 **Exploded, schematic view of the bed, flow pattern and free surface at a stream confluence. Collision of the two incoming streams raises the free surface and forces a downwelling flow along the boundary of the paired helical vortices, resulting in a deep scour on the bed and, as discussed here, a scour hole such as that identified by Best and Ashworth[1].**

As this downwelling water is driven sideways and back up again by the bed, all the while being carried downstream by the mean flow, it wraps back on itself to form a pair of powerful, counter-rotating vortices like those behind a twin-screw power boat. The downwelling region along the boundary of

Living with the Land Ethic

A. CARL LEOPOLD

The legacy of Aldo Leopold includes the concept of ethical responsibilities toward the land, and the establishment of ecological restoration both for environmental learning and for land management. For more than a half-century, the land ethic has been a major paradigm for ethical and environmental thinking.

Keywords: land ethic, ethical responsibility, ecological restoration

In 1988, Alvin W. Trivelpiece, then executive director of the American Association for the Advancement of Science, mailed a questionnaire to professional scientists asking them to look back at their training in science and identify the most important omissions in their own education. Their responses identified the highest priority as a need for a better background in ethical principles (Trivelpiece 1988). This is in line with the perception by Derek Bok (1988) that universities had exhibited a decline in ethical teaching since the 1800s. Bok sensed a growing need to provide students with training in ethical thinking about complex issues, especially in the face of increasing reductionism in the sciences.

Although there may have been a drift away from education about ethical principles, a substantial interest in ethics persists. Yet the focus on ethical issues among academic faculties seems to be hugely dominated by anthropocentric concerns—ethical relations among people, and particularly between professionals and their clients or colleagues (including medical ethics, business ethics, and honesty ethics). This anthropocentric focus is evident in the *Encyclopedia of Applied Ethics* (Chadwick et al. 1998), a four-volume set of definitions of ethics relating to interactions among people, which contains only one entry about ethical relationships between people and the environment.

Estrangement from nature

Given the evidence that professional training in the sciences has been short on education about ethical issues, and especially about ethical relations to the environment, we might ask how our society has become estranged from these ethical concerns. Why has there been so little concern for ethics relating to the biological system that sustains us (Orr 1992)?

Surely our sense of identity with nature has changed as our culture has changed. For example, people living in low-technology settings, such as the Inuits in the Arctic and hunter–gatherers in Africa and Australia, must maintain a high level of sensitivity to their environmental resources. Their survival depends upon it. Indeed, not only are people in those societies directly dependent on the natural world, but in many cases they maintain a sense of affection for its living components (Lopez 1986)—a sort of environmental aesthetic.

In an agrarian society such as the one that brought farming and ranching to the settlement of North America, people must have retained some sensitivity to environmental issues as they derived their livelihood directly from the land. But with the advance to an urban or metropolitan society, there has been a major disconnect between humans and nature. Our urban society is provided with mowed parks, paved playgrounds, plush automobiles to move us around on asphalt roads, housing with automatically regulated heat and cooling, and supermarkets with wheely baskets in which we can gather our food supplies from orderly shelves. This human-built environment (the techno-ecosystem of Naveh [1982]) serves to buffer urban society from the untamed biological world. The buffering is evident in homes, in play, in recreation, in travel, and in the act of acquiring food and supplies. It is

A. Carl Leopold (e-mail: ACL9@Cornell.edu) is an emeritus scientist at the Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, NY 14853. He is currently involved with several ecological organizations for the promotion of ethical responsibilities to the land, the restoration of the rain forests in Costa Rica, and the protection of quality lands in the Finger Lakes region. *This article is an expanded version of "Living with the Land Ethic," a plenary address delivered at the 54th annual meeting of the American Institute of Biological Sciences, held in Arlington, Virginia, 21–23 March 2003. The original address may be viewed online at the AIBS Virtual Library:* http://aibs.digiscript.com/presentation/index.cfm?media_id=10948.

easy to see how families can become alienated from the system of nature that sustains us. And the contemporary expansion of affluence and consumer lifestyles can further promote alienation from nature.

The 2003 AIBS symposium on bioethics (Dybas 2003) was intended to increase awareness of our dependence on the natural world and to promote awareness of the extent to which we are insulated from it. Ethical teaching should be promoted in science programs, including an emphasis on ways to encourage an ethical relationship with the land and on the mutual enhancement between ethics and aesthetics (Orr 1992). Might we do that through our own lifestyles as well as through our educational system? Teaching the concept of ethical responsibility for maintaining (and restoring) quality environments may promote a gentler lifestyle and a greater realization of the aesthetic qualities of the world around us. This may be the paramount heritage from Aldo Leopold's land ethic (Leopold 1949).

Reentry into the natural world

Awareness of the natural world and its resources, and subsequent concern for their preservation, can be generated by nurturing a knowledge of and affection for the land. I would like to describe the development of my own awareness of an ethical–aesthetic relationship to the land and how it was nurtured by my father, Aldo Leopold, beginning with our happy family immersion into ecological restoration. At the same time, I may give you a glimpse into Aldo Leopold's most important professional experiment, his effort to use ecological restoration as a viable part of environmental learning.

In 1934, a group of professors at the University of Wisconsin persuaded the administration to allow them to revamp the university arboretum, restoring the various types of native vegetation that were typical of the region. Besides Aldo Leopold, this group included Professors John Curtis, Norman Fassett, and Bill Longenecker. In a speech celebrating the start of the arboretum remodeling, Leopold stated, "The function of the Arboretum is to serve as a...starting point in the long and laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape" (cited in Meine 1988). I infer that in mentioning a mutually beneficial relationship, Leopold was thinking of the beneficial effects on the landscape through the efforts of people doing the restoration and, conversely, the beneficial effects on the people involved through their better understanding of the landscape.

As the effort at restoration of native landscapes began in Madison, Leopold became so intrigued with the concept of restoration that he wanted to try the idea for himself. The next year he purchased 80 acres along the Wisconsin River for his "shack"—a place where he could attempt restoration for himself and, at the same time, walk his entire family through the venture.

When my father announced at the dinner table that he had purchased a piece of property along the Wisconsin River, I entertained illusions of a place of beauty and comfort, perhaps a vine-covered cottage from which we would gaze down at the flowing river. It was a considerable surprise to me, then, when the newly acquired place turned out to be a devastated landscape. It was a marginal property in a floodplain that had been farmed until the sandy soil was exhausted and the wind blew it away. After the farmer gave up and left, the farmhouse was used by a bootlegger who stayed until his mash caught fire and the house burned down. The property was abandoned, after which the bank sold the place to Aldo Leopold for taxes at $8 per acre.

On the abandoned farm, there remained one crumbling shed. The family's first project was to clear the manure from the shed and rebuild it into a place where we could stay on weekends and vacations. Once the shack had been rebuilt (figure 1a), my father began the work of ecological restoration. With the help of his family, relatives, and friends, he started planting (figure 1b). There were thousands of pine seedlings to be planted; bushels of acorns and nuts to be heeled in; carloads of aspens, shrubs, and wildflowers to be hauled in and transplanted; heavy mats of prairie grasses to be laid; and seeds of prairie flowers to be sown.

The shack now stands in a mixed pattern of restored forest, prairie, and wetlands (sites after restoration are shown in figure 1, photographs c, d, and e). For my father, the property became a sanctuary of ecological beauty and inspiration. For 14 years, he lived to enjoy the product of his personal restoration program. It fueled his love affair with writing, especially about his observations and the joys that he found there. His essays in *A Sand County Almanac* (1949) illustrate the delights that the restoration work evoked in him. In fact, on the day of his death (while fighting a neighbor's grass fire), he was out on the farm planting pine trees.

For his children, the family efforts at ecosystem restoration resulted in a deep enthusiasm for environmental issues. Each of my four siblings and I became a professional in some aspect of environmentalism. Each of us has published treatises on some aspect of restoration ecology, and each has been given an honorary doctorate for our work. My sister Nina became an expert on the restoration of prairies in Wisconsin, and I have been working over the past 10 years on an effort to restore tropical rain forest in Costa Rica (Leopold et al. 2001). My siblings and I have combined our resources to form the Aldo Leopold Foundation, an organization centered on the property around the shack, where restoration work continues. The foundation is dedicated to the promotion of ecological literacy and the land ethic.

The story of the shack is not just a tale of a happy family project. It is the story of the origin of two new concepts in environmentalism: ecological restoration and ethical responsibility toward nature. Each of these concepts has become a major component of contemporary environmentalism. The story is a metaphor of the contagious value of restoration in bringing people back to the natural world in a mutually beneficial relationship. At the same time, it fortifies a personal sense of ethical responsibility to the natural world.

Figure 1. Samples from Aldo Leopold's restoration on his shack property in Wisconsin. (a) The shack in 1935, before land restoration had begun. (b) Aldo and his wife, Estella, at an early stage in the restoration planting. The next three photographs show the site 65 years later: (c) the restored shack environs, (d) restored prairie, and (e) Leopold's restored forest. Color photographs: Courtesy of Michael Sewell/Visual Pursuit.

Conservation has traditionally focused primarily on the preservation of ecological capital (Daily et al. 1997)—on reducing consumption and acting to preserve ecological remnants. Aldo Leopold's example added a distinctive new component to conservation: positive actions to restore ecological communities. Again we see the mutually beneficial relationship that can come from restoration, which not only serves to increase the ecological quality of a site but also generates environmental thinking on the part of the participants. Ecological restoration may be a prime way to educate people in developing an ethical attitude toward the land.

Of course, the concept of ethics and aesthetics playing important roles in conservation was leavening in Leopold's mind for much of his life. Ethical concepts began to appear in his writings as early as 1933, in his book *Game Management* (Leopold 1933a) and then in his article "The Conservation Ethic" (1933b). After three years of his own restoration work at the shack, he began to focus on conservation aesthetics (Leopold 1938), writing a series of essays that celebrate the role of beauty and inspiration in conservation. Ultimately, Leopold's major statement combining the ethic with the aesthetic was assembled in his collected essays *A Sand County Almanac* (1949).

There is more to say about the aesthetic issue. It is rare indeed for a scientist to write professionally about love and affection. But Aldo Leopold repeatedly called on these aesthetic values; for example, he stated that "we can be ethical only in relation to something we can see, feel, understand, love, or otherwise have faith in" (Leopold 1949). Leopold's emphasis on aesthetic values along with ethics has been paraphrased nicely by Schmidtz and Willott (2002), who write, "Environmental ethics teaches us how to enjoy the world, not just how to fix it."

Ontogeny of bioethical concepts

Writers of natural history who preceded Leopold, such as Henry Thoreau, George Marsh, and John Muir, perceived nature as beautiful in its complexity and suffering damage from human exploitation. But it remained for Aldo Leopold to develop the concept of people having an ethical responsibility toward nature. He was the first to write about a "conservation ethic" and, later, a "land ethic." There has been a subsequent array of variations on the theme of environmental ethics (some examples are outlined in figure 2). Albert Schweitzer (1959) included the idea of "an ethical world" in his discussion of "reverence for life." He stated that human beings are ethical when they obey the compulsion to help all life. Rachel Carson (1962) may be included in this ethical sequence; she argued that it is insufficient to concern ourselves with the relation of humans to one another. Instead, she stressed the relation of humans to all life. Later, in the 1970s, a drift began toward bioethical concepts in which mankind is not taken to be the central orientation of nature but instead is considered to be only a member of the planet's natural community of life. An example is the concept of "deep ecology" (Naess 1973, 1989), which rejects the human-centered perspective on nature and shifts the ethical issue to a biocentric base. This point of view resonates with Aldo Leopold's assertion that the "land ethic... changes...the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it" (Leopold 1949).

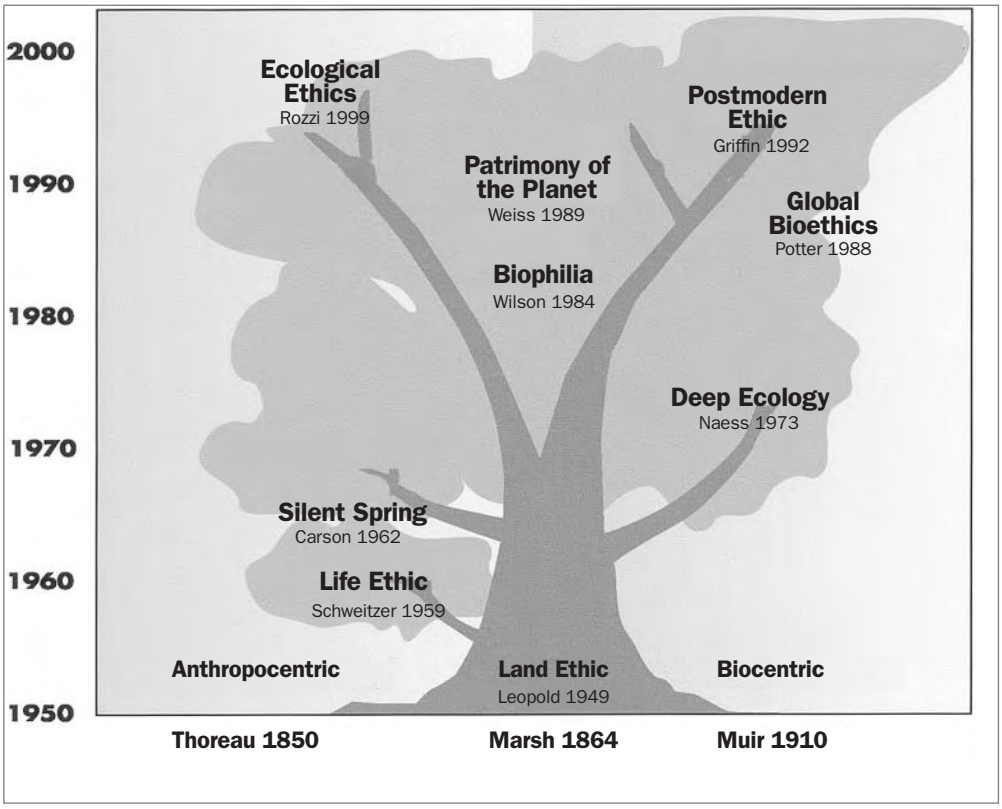

Figure 2. Some examples of bioethical concepts that have emerged since the land ethic was introduced in Aldo Leopold's* A Sand County Almanac *(1949).

The drift away from anthropocentric and toward more biocentric ethical concepts has continued over the past 25 years of ecological thought. Examples of biocentric environmental thought include Potter's bioethic (1971) and global bioethic (1988) and Griffin's postmodern ethic (1992). Contemporary ethical thought along a more anthropocentric line might include Edward O. Wilson's proposal of "bio-

philia" (1984) and Rozzi's mutually interactive ecological science and ethics (1999). Weiss's "patrimony of the planet" (1989) proposed a planetary ethic centered on an inherent responsibility for providing a legacy for future generations.

Such variations on the theme of environmental ethics reflect an elaboration and refinement, progressing beyond the simple statement of the "golden rule" toward a set of ecological guiding principles—principles that can bring aesthetic dividends even as they promote a state of harmony between humans and the natural world. Collectively, they seem to me to open the way toward a more balanced sense of responsibility—a moral baseline for human behavior toward our natural world systems.

The land ethic as a new paradigm

The entry of ethical concepts into ecological thinking has provided a powerful new guiding principle. Kuhn (1970) defined the difference between guiding principles and ordinary professional contributions. Guiding principles provide an intellectual structure that reorients thought in a way that is persistent over a relatively long period of time. By contrast, ordinary contributions have a relatively limited persistence in professional thinking. To illustrate the difference, one can appraise the usefulness of a concept over time. The duration of a publication's usefulness can be defined by the period of time over which it is used or cited. Professional librarians have described the frequency at which books are checked out from libraries as a decaying curve, with a midpoint (a half-life) occurring on average about 5 or 6 years after publication (Margulis 1967). Data from the Institute for Scientific Information now permit an alternative means of estimating the duration of a book's usefulness, using the frequency of citations in the published literature. For example, figure 3 shows a plot of the frequency of citations of my book *Plant Growth and Development* (Leopold 1964). The usual type of decay curve of citation frequency has occurred, showing a half-life of approximately 6 years. Using the frequency of citations of Aldo Leopold's *A Sand County Almanac* (1949), a contrasting time course is seen. There were almost no citations for more than a decade, after which citations have been rising consistently for the subsequent 50 years (figure 3). It is evident that Aldo Leopold's book is having an impact over a long period of time, as is consistent with the definition of a new guiding principle.

Following the terminology of Thomas Kuhn, a new guiding principle constitutes a new paradigm. A new paradigm provides an altered sense of order, a new center of orientation. Its persistence is consistent with its effecting a long-term change on science. The occurrence of a new paradigm is the structural basis for revolution in science. True to Kuhn's expectation, Aldo Leopold's new paradigm of the land ethic—a new perspective on conservation ecology through ethical precepts—has led to the appearance of new journals, new professional societies, and numerous new books concerned with environmental ethics.

Fostering ethical concerns

There remains a major question of how to nurture an awareness of the land ethic in the public arena. For individuals, such ethical nurturing is often triggered through the influence of an inspirational mentor—a parent, a teacher, or a peer group. A reading experience can also be a powerful stimulus of concern for the land; for example, people often tell members of Aldo Leopold's family that reading *A Sand County Almanac* changed their lives and motivated them to enter an environmental profession. The sense of ethical concern can also be nourished by participation in community actions such as planning boards, land trusts, recycling, and resource conservation functions. Of course, any of these ways of becoming engaged in ethical concerns can be strengthened by hands-on involvement in land restoration.

Forces in conflict with bioethics

As part of a discussion on bioethics in a changing world, we should take the measure of the conditions or forces that clash with or simply override ethical considerations. Some examples include greed, poverty, and war. Greed can be a major force in driving excessive exploitation of natural capital, such as excessive mining, excessive removal of oceanic resources, or reckless cutting of forests. Insatiable appetites for personal aggrandizement and ostentation often override ethical considerations. Poverty, too, can be expected to nullify ethical considerations in relation to the stewardship of the environment: Impoverished people often use natural resources badly. The occurrence of wars leads to the suspension

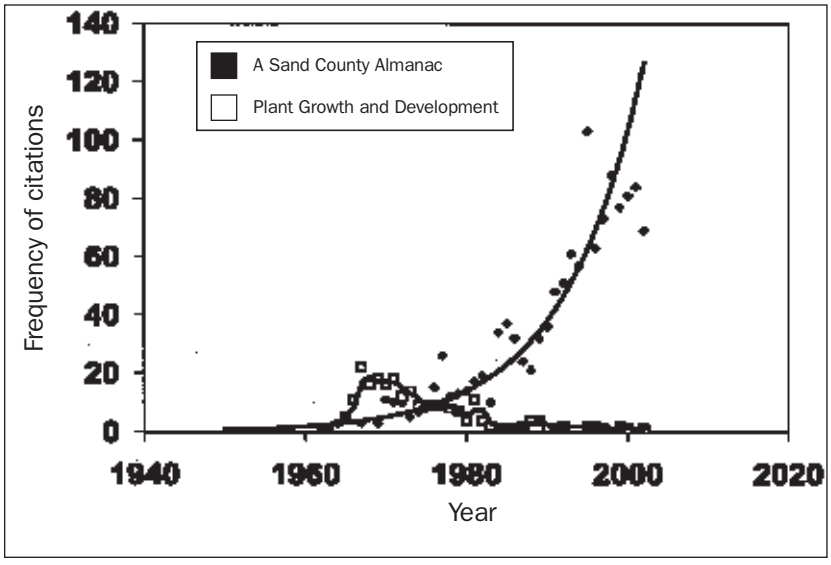

Figure 3. Comparison of the frequency of citations of Aldo Leopold's book* A Sand County Almanac *(1949) with those of A. Carl Leopold's book* Plant Growth and Development *(1964).

of practically all ethical principles, not only at the personal, social, and political levels but also at the biological and environmental levels. These three examples of forces in opposition to ethical actions occur with alarming frequency in our nation and in many other parts of the world.

The extent to which Aldo Leopold's ethical concept will persist in our society is likely to depend upon the extent to which such conflicting forces can be restrained. It is reasonable to assume, for example, that involvement of people in the restoration and protection of quality land may increase their sensitivity to rates of resource consumption and possibly to issues of poverty and peace. As we discuss the positive values of bioethical principles, we must keep a special awareness of the massive ethical costs of war.

Conclusion

There is a perceived need among professional scientists for more knowledge about ethics. As human lives have come to revolve around urban centers, the need for a better understanding of bioethics, and specifically for an ethics-based strategy for environmentalism and conservation, has become more acute. Aldo Leopold's statement of the land ethic, which extended the concept of conservation to include restoration ecology, fills such a need. The emergence of Leopold's land ethic has been followed by an elaboration of ethical concepts in relation to biology and conservation, as would be expected with the advent of a new scientific paradigm.

It is important to be aware that bioethics are susceptible to violation, or even destruction, by social dysfunctions such as greed, poverty, and war. A part of the costs of this social dysfunction will necessarily be a corrosive effect on bioethical principles and a deterioration of harmony between humans and their natural environment. Remember Aldo Leopold's statement of the land ethic (1949): "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Despite these obstacles, we can hope that the land ethic will continue to grow, that mentors and teachers will guide students toward this goal, and that ecological restoration will be used to provide leverage for fostering ethical ideals in students, coworkers, family, friends, and ourselves.

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